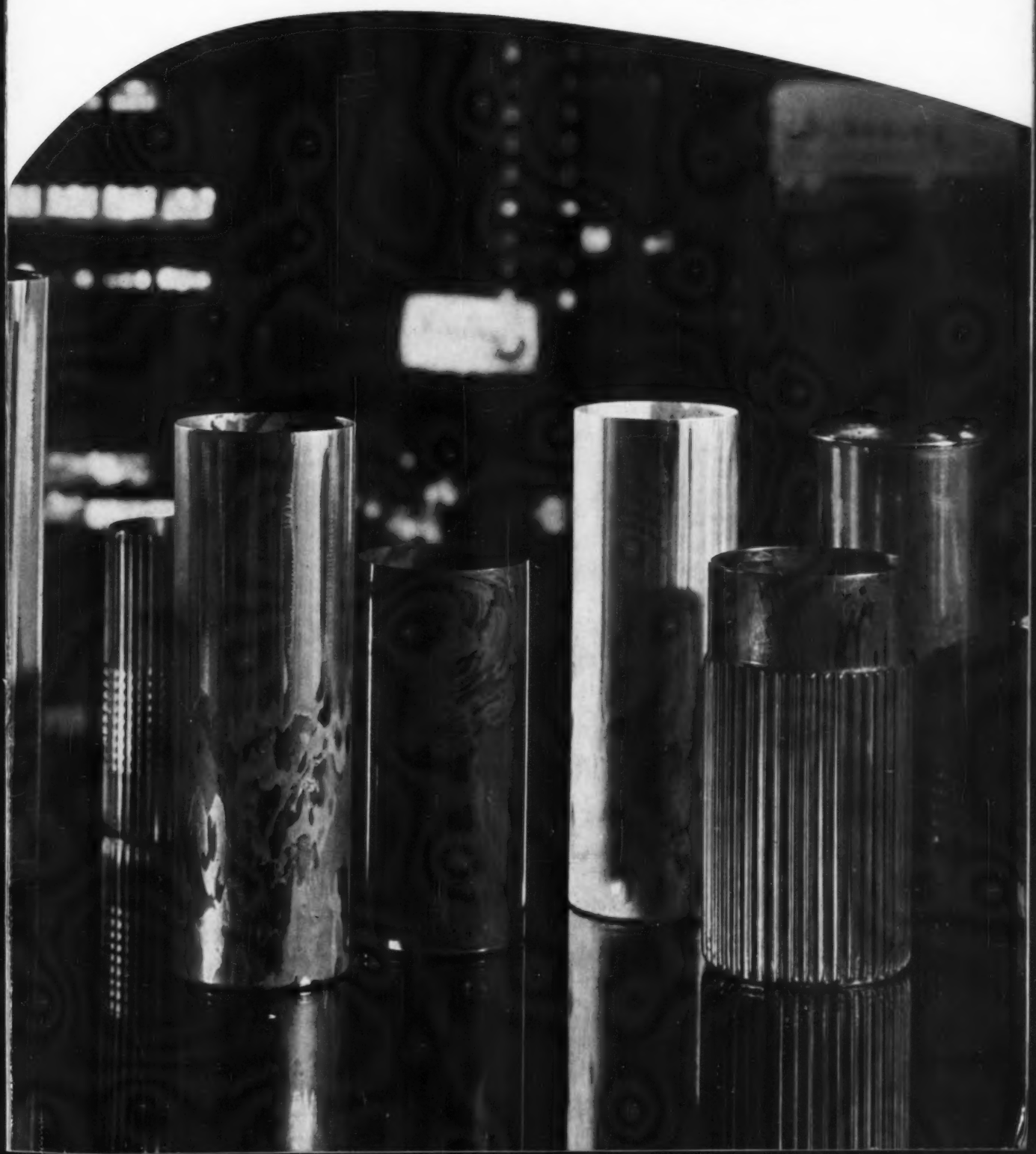
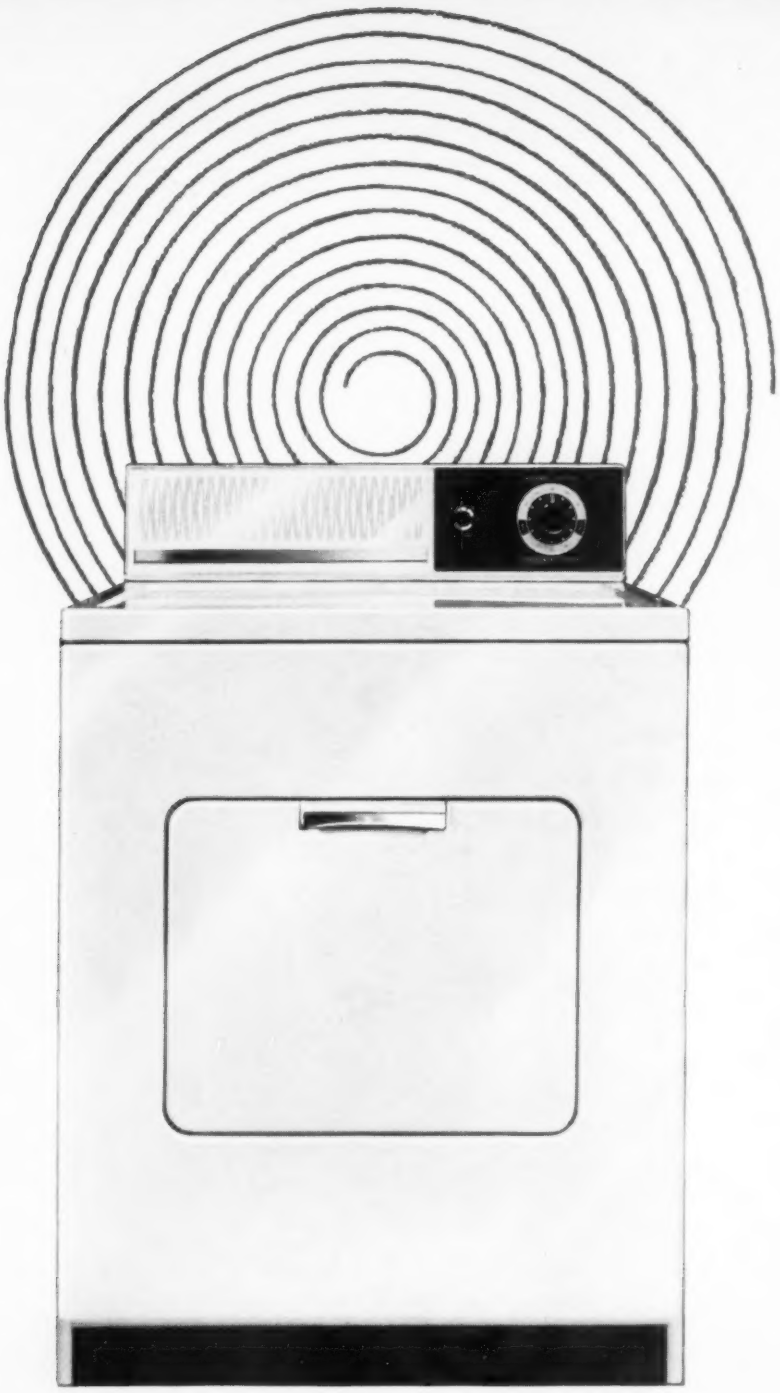
METAL PROGRESS

August 1961





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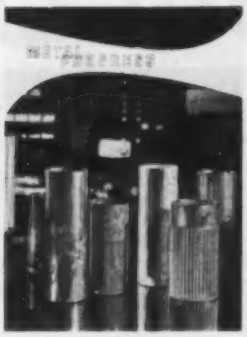
Lee Wilson

ORIGINATORS AND LEADING PRODUCERS OF OPEN COIL AND SINGLE STACK FURNACES

Metal Progress

August 1961 . . . Volume 80, No. 2



COVER: The colorful cylindrical shapes on our cover (shown against a background of New York's midtown skyline at night) are a preview of Alcoa's "Varaflow", a special form of aluminum incorporating integral variegations of color. More details are given in "Impacts in Color" on p. 96.

Technical News in Brief

High-Energy Machine Forges Close-Tolerance Parts . . . Thick-Walled Pipe Made by High-Frequency Welding . . . Bright Future for Low-Temperature Metals . . . New Method for Producing Metallic Coatings . . . How Water Affects Quenching Rates of Salt Baths . . . Large Electron-Beam Furnace Refines Refractory Metals . . . Computer Controls Production of Carbon Resistors . . . Deforming Metastable Austenite Produces New Strength Levels. 7

High-Energy Forming

How to Design for Explosive Forming, by Vernon H. Monteil 66

The process is not a cure-all for forming difficulties but is a good supplemental technique that is useful in shaping difficult materials and large parts.

Ryan's Experience in Explosive Forming, by Floyd A. Cox 71

Explosive forming can simplify fabrication of complex shapes and produce close-tolerance parts. Some examples of what can be done with the new technique point out its potential to design engineers dealing with tough forming problems.

Steel Parts Formed on High-Energy-Rate Machine, by Ralph G. Monsees 74

High pressures applied at great speeds permit parts to be extruded or forged in one stroke to close tolerances and smooth surfaces. These characteristics open areas of application of high-energy machines to conventional metals such as resulfurized steels as well as those which are difficult to form.

Explosive Forming With Combustible Gas Mixtures, by John Miller and Philip Kruse 76

Working with mixtures of hydrogen, oxygen and an inert gas, Boeing engineers are experimenting with a forming method which possesses the advantages of conventional explosive forming but eliminates some of its limitations. Forming pressures can be controlled more accurately and the combustible gas is, in effect, an ideally shaped charge since it is always in contact with the workpiece.

Nondestructive Testing for Management — IV

Factors to Consider in Selecting Ultrasonic Testing Equipment, by R. A. Seidel 83

In choosing an ultrasonic instrument for flaw detection, ruggedness, degree of accuracy needed, ambient illumination conditions, instrument stability, dependability, simplicity of operation, size, weight, and portability are all important factors to consider.

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The coding symbols on articles in Metal Progress *refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

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Metal Progress

No. 8 in a Series on Better Finishing

How to Get the Most From Phosphating Systems—I, by George H. Pimbley 103

The first of three, this article describes some of the recommended practices for zinc phosphate dip baths. In subsequent issues techniques for getting best performance from zinc phosphate spray systems and from manganese and iron phosphate systems will be presented.

Engineering Articles

Computer Helps Speed Heat Cycles, by C. L. Feng 79

An analog simulator, termed "Thermolog", has proved useful in obtaining hard-to-get information necessary for designing and evaluating thermal systems. Specialized heat problems can be solved in a few hours after set up of the simulator circuitry.

German Commentary on Turbine Failures, by S. Ammareller and P. Gruen 89

Failures in Europe in the 1920's led German metallurgists to use a low-alloy steel of good hardenability, oil quenched and tempered for high strength and ductility. Recently, vacuum pouring has eliminated danger of flaking.

Residual Welding Stresses in Aluminum Alloys, by H. N. Hill 92

Fusion welding produces residual stresses in the vicinity of the weld that are about equal to the minimum yield strength in the heat-affected zone. These stresses do not impair the ability of a welded structure to resist static or impact loading.

Electrolytic Polishing of Refractory Metals, by F. R. Cortes 97

A versatile solution, composed of small amounts of sulfuric and hydrofluoric acids in methanol, can be used to electropolish four refractory metals – molybdenum, tungsten, tantalum and columbium. Grinding and polishing procedures are also described.

Centrifugal Casting of Thin-Walled Magnesium Parts, by Warren C. Smith 101

For complex shapes difficult to produce, the centrifugal process is providing sound magnesium castings that are often metallurgically superior to those produced by other casting methods.

Metal-Metal Oxide Composites for High-Temperature Use, by Klaus M. Zwilsky and Nicholas J. Grant 108

Given the same base metal, dispersion-strengthened composites are stronger (at higher temperatures and for longer times) than their counterparts in age-hardening alloys.

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Metal Progress is published monthly by the American Society for Metals. Publication office Mt. Morris, Ill. Editorial and general offices Metals Park, Novelty, Ohio. Second-class postage paid at Mt. Morris, Ill., and at additional mailing offices. Vol. 80, No. 2, August 1961.

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PRESS BREAKS

As time goes on, we hear more and more about "materials" development and education as an aid in solving many of tomorrow's space age, atomic and "everyday" problems. In fact, ten schools (Columbia, M.I.T., Northwestern, Stanford, Purdue, Michigan, Cornell, Cincinnati, Arizona, and Penn State) already offer degrees in material engineering (or materials science). This trend toward a unified materials approach was clearly brought out during the annual meeting of the *Metal Progress* Editorial Advisory Committee, a group of experts whose names appear on our masthead each month.

The group includes representatives from metal-producing and metal-consuming industries, "far-out" research organizations and "day-to-day" manufacturing concerns. Technical leaders from the aircraft, missile industries, atomic energy, automotive, electrical manufacturing and educational fields are all members of the Committee. They assist the

Metal Progress *Editorial Advisory Committee Confers at A.S.M. Headquarters. Standing, left to right: John J. Chyle, A. O. Smith Corp., Chairman; Fred L. Siegrist, Asst. Editor; Ralph G. Dermott, Managing Editor; James Holzwarth, General Motors Corp.; Carl R. Weymueller, Assoc. Editor; Arthur D. Schwope, Clevite Corp.; R. J. Gray, Oak Ridge National Laboratory; Donald E. Nulk, Combustion Engineering, Inc.; Allen G. Gray, Editor. Seated, left to right: R. H. Gassner, Douglas Aircraft Co.; Donald R. Johnson, Sandia Corp.; D. C. Goldberg, Westinghouse Electric Corp.; Elliot A. Reid, Bethlehem Steel Co.; G. M. Ault, National Aeronautics and Space Administration; W. W. Austin, North Carolina State College; W. L. Fleischman, General Electric Co.*

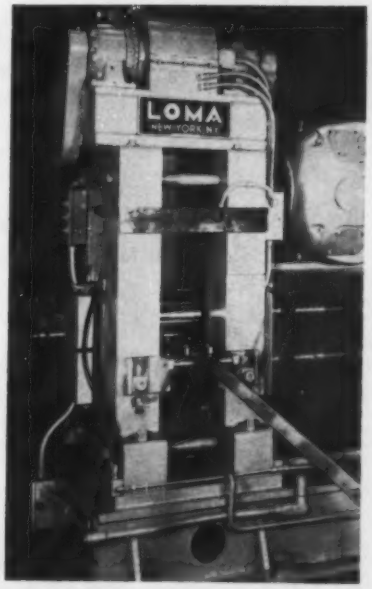
editors in keeping abreast of important developments in metalworking technology and, in fact, each of the Committee members was asked to serve with the idea that he would advise the editors on technical matters in the field of his own competence.

The two-day affair was a stimulating give-and-take on all aspects of materials and processing under the tactful chairmanship of genial Jack Chyle. It was interesting to the editors to hear members of our Committee say that the ideas they took away with them will stimulate their own action on new approaches to their company's problems. Look for coming issues of *Metal Progress* to reflect some of the thinking from this important meeting.

The Editors

NEWS FROM

LOMA



A wide variety of metallurgical processing work can now be performed by a single mill facility due to the development of this compact and versatile LOMA 2-high/4-high Combination Rolling Mill. The equipment is suitable for both hot and cold work, and allows both shapes and flat stock to be rolled, with or without the application of tension.

The machine is equipped with extra large capacity mill housings, roll journals, universal spindles and drive transmission. This heavy-duty design allows the mill to take reductions of more than 50 per cent per pass while maintaining tolerances as close as 5 per cent of thickness.

Change-over from the 8½ in. x 10 in. 2-high to the 2½ in. & 8½ in. x 10 in. 4-high setup requires only 30 minutes. The 2-high arrangement is used for either hot or cold breakdown rolling of plate and sheet, and grooved rolls are also available to process rounds, squares and other shapes. In the 4-high setup strip is cold finish rolled to gauges as thin as 0.002 in.

The LOMA mill is furnished with high-strength steel housings, twin-handwheel or dual-motor wormdrive screwdowns, universal joint spindles, herringbone gearing, and an extra heavy-duty 25 h.p. variable-speed drive. The rolls are made of forged alloy steel and are hardened to 100 Shore Scleroscope. The roll necks are mounted in super-precision needle roller bearings having a total separating force capacity of 350,000 lbs. The bearings are continuously lubricated by a closed oil circulating system.

LOMA
MACHINE MFG. CO., INC.
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New York 16, N. Y.

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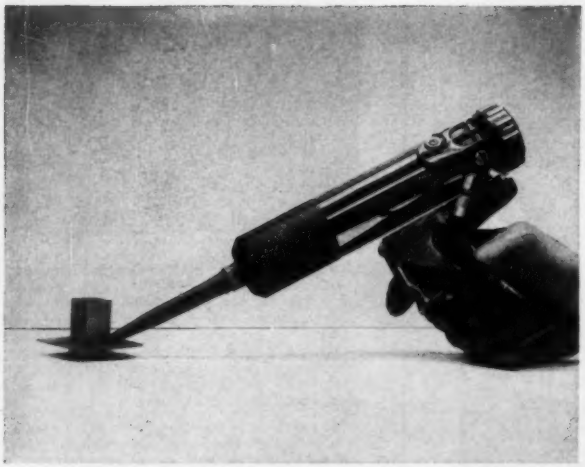
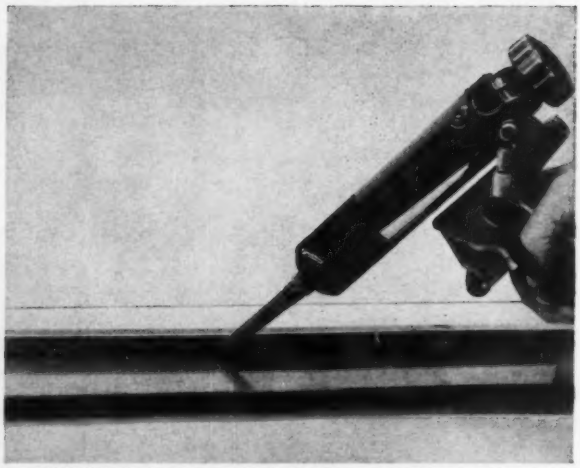
Now-join aluminum with new ease

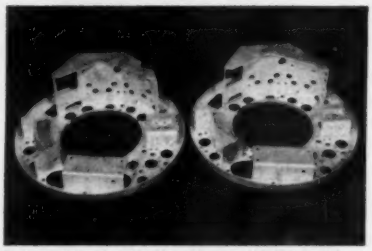




Applied with equal facility to small joints or large seams, new Alumibraze "400" is the fast, convenient way to braze aluminum parts.

If your work involves joining aluminum alloys, there's a good chance you're already familiar with the advantages of Handy Alumibraze—the salt bath brazing method that provides strong, sound, corrosion-resistant joints—with excellent reproducibility—more readily than preforms—while reducing tool and fixture costs.

Now, Handy & Harman has developed a new preparation—Alumibraze "400"—for even greater ease of application. Containing the same active ingredients as before, Alumibraze "400" is formulated to provide a homogeneous paste that can be extruded onto parts by a gun or other method.



Extrudable Handy Alumibraze "400" is ideal for brazing complex assemblies like these.

Think of the trouble this saves you. You can join extended areas and complicated contours more conveniently than ever before. Cut application and assembly times way down. Reap all the benefits of high-volume production.

Don't let another day go by without learning how Alumibraze "400" can speed operations in your shop. Our recently-expanded Bulletin 23 supplies full details. It's yours for the asking.

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High-Energy Machine Forges Close-Tolerance Parts

The case histories presented on p. 74 indicate that high-energy machines are capable of forming parts which require little or no subsequent machining. This advantage has been confirmed by experimental work at American Brake Shoe Co. in Mahwah, N.J. Metallurgists at the company's Research Center, working with a vertical Dynapak machine (model 1810) report that they have formed shapes of 4130 steel, copper and copper powder to close dimensional and surface-finish tolerances. The steel part, for example, a cone-shaped piston cap for a landing gear strut, has been forged in one stroke in the high-energy machine to a wall thickness of 0.180 in. ±0.005.

In forging nozzles for oxygen lances from copper billets and copper powder compacts, the fast forming speeds (ram velocity can reach 1500 in. per sec.) give parts a fine-grained structure, a desirable characteristic because it improves stress-rupture life at elevated temperatures. Dr. Hugo Larson, research metallurgist at Mahwah, said that experiments with dispersion-hardened powder compacts containing 2 to 7 vol. % alumina in a copper matrix demonstrate the feasibility of distributing the oxide at the tip of the nozzle where the highest temperatures are reached. The dispersed oxide strengthens the copper and raises the recrystallization temperature. (These advantages are pointed out in "Metal-Metal Oxide Composites for High-Temperature Use" beginning on p. 108.)

Nozzles have also been made from billets of tough pitch copper. Starting with a billet weighing 9.1 lb., forging on the Dynapak produces a part which weighs 8.9 lb. when a slight amount of flash is removed. Although the nozzle has a 1¼-in. diameter by 2½-in. deep hole, it can be formed in one blow. A shallow thread (one or two turns) cut in the female die holds the formed part in place just long enough to allow the ram to be withdrawn. As the forging cools, it contracts enough to be lifted out of the die.

Thick-Walled Pipe Made by High-Frequency Welding

The important advantage of high-frequency welding for making stainless steel tubing and pipe comes from the short heating and cooling cycles that are used. Fast heating, welding and cooling result not only in high production rates but metallurgical benefits as well. This has been demonstrated recently at Acme Tube, Inc., Irvington, N.J., whose engineers announced the development of high-frequency welding equipment which will produce stainless tubing – primarily the austenitic grades – in sizes of up to 6-in. O.D. and in wall thickness of up to 0.154 in., a significant increase from the usual limit of 0.095 in. for stainless tubing fabricated by high-frequency welding. The thick-walled tubing can be made to I.D. and O.D. tolerances of at least ±0.006 in. Even at 0.154-in. wall thickness the welding cycle is so fast (at least 20 ft. of pipe can be welded per min.) that the steel, although not the low-carbon variety, is not sensitized. Provided sensitization does not occur when the pipe is welded in the field, then users can take advantage of important

Technical

NEWS

In Brief

cost savings. The standard-carbon steel is less expensive than the low-carbon grades and since the weld area is not sensitized, it need not be heat treated to get rid of carbides at grain boundaries.

Engineers at Acme Tube say that the 0.154-in. limit in wall thickness is determined by the ability of the equipment to roll the steel before it is welded. Despite careful control of the heat pattern, they see a limit of 0.250 in. as a practical maximum wall thickness above which welding difficulties arise.

Bright Future for Low-Temperature Metals

An outstanding feature of the recent meeting of the American Society for Testing Materials was a two-day symposium on evaluation of materials for low-temperature service. While a great deal of the interest in metals for low-temperature uses has been due to military applications, the change in missile propellants to liquid fuels that are storable at ambient temperatures and solid propellants has brought about a shift in emphasis for manufacturers of cryogenic equipment. Producers of cryogenic tanks and hardware now fully expect that the increased use of cryogenic fluids for industrial applications will more than make up for the slack in government interest.

Reasons for the increased need for cryogenic facilities by industry were brought out by Herbert W. Marsh, chief engineer of advanced designs, Graver Tank and Mfg. Co., East Chicago, Ind., who stated that by 1965 the use of oxygen in steelmaking (see *Metal Progress*, June 1961, p. 97) is expected to exceed 800 cu.ft. per ton. This compares with 250 cu.ft. of oxygen used per ton of steel produced in 1959. The basic oxygen process requires 2000 cu.ft. per ton of steel, and the use of oxy-fuel lances for open-hearth steelmaking will require some 500 tons of oxygen per day for each open hearth.

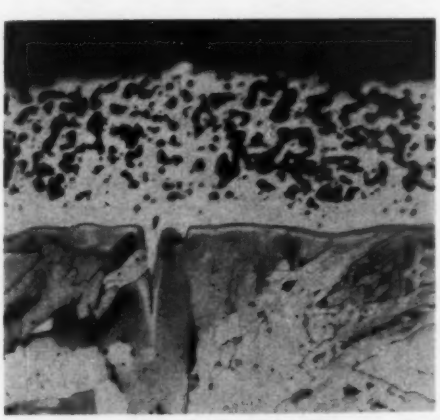
Mr. Marsh pointed out that as a result of the increase in oxygen production, a large amount of liquid nitrogen is available at low cost. A good part of this will be used as an in-process refrigerant and for liquefaction of hydrogen and helium. Nitrogen gas provides an inert atmosphere for packaging food products, for galvanizing and for production of tin plate. The increased production of ammonia is requiring more facilities for storage of larger quantities of both hydrogen and nitrogen and interest in storing these gases in the liquid state is growing.

A new field, yet undeveloped but with great potential, is storage of liquid methane. If this becomes commercial, it will most likely be the largest single application for low-temperature storage tanks.

New Method for Producing Metallic Coatings

Recently, Armour Research Foundation, Chicago, announced that its engineers were now coating parts by an intriguing new method. According to H. T. Francis, this technique involves flame-spraying the metallic oxide on a surface, and then reducing the oxide in a stream of hydrogen. Already having been successful with nickel oxide, the method appears readily applicable to any easily reduced oxide – copper, tungsten, iron, and molybdenum, among others.

An adaptation of "flame ceramics", this process employs a special oxy-hydrogen torch, equipped with a device which feeds a continuous, even, entrainment of powdered ceramic into a gas stream. As the oxide passes through the flame, it is brought to a semimolten state. When the flame is directed against a suitable material, "tacky" oxide particles strike at high velocity to stick to the surface. If nickel oxide is used as the "ceramic", it produces a dark gray matte coating. Treatment for 1 hr. at 1100° F. in hydrogen then reduces the oxide completely, and an excellent bond develops between the nickel and the steel base (see photo). Though the outer zone of the coat is somewhat porous, the



PURE NICKEL COATS STEEL BASE (250 ×)
Flame-Sprayed Nickel Oxide Is Reduced in Hydrogen

Technical NEWS

In Brief

layer of nickel adjacent to the steel base is dense and continuous.

On the theoretical side, according to Dr. Francis, "Simultaneous reduction and sintering of metal powders yields much better densification of the product metal than does mere sintering of an already metallic powder". In powder metallurgy, this phenomenon is known as "activated sintering", the activation being accomplished by partially oxidizing a green compact before sintering in hydrogen. Therefore, in this coating method, activation is an inherent feature because the metal exists completely as an oxide.

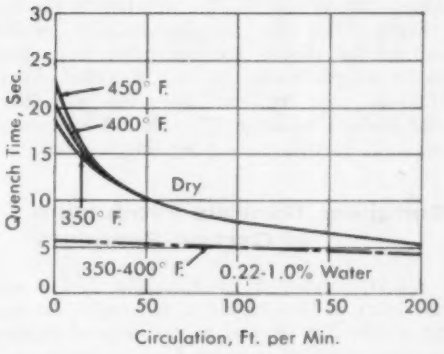
Useful applications for the method are promising. Dr. Francis suggests that aircraft parts can be clad with nickel to resist both marine exposures and moderately high temperatures. Other space-age applications will probably appear with further research efforts.

How Water Affects Quenching Rates of Salt Baths

Many heat treaters have known for some time that small amounts of water added to nitrate-nitrite salt baths will increase quenching rates appreciably. The curves shown on this page present some quantitative determinations of this effect. As reported by H. J. Gilliland of the General Motors Technical Center, Warren, Mich., these measurements were made with the "Quenchometer" (see *Metal Progress*, October 1960, p. 111).

Briefly, the curves show quenchometer readings in seconds (to cool a 1-in. diameter nickel ball from 1625° F. to 670° F.) plotted against the degree of quenchant circulation. As is apparent, the quenching speed of dry salt is greatly increased by circulation, whether the bath temperature is maintained at 350, 400 or 450° F. Conversely, when 0.22 to 1.0% H_2O is added to salt maintained at 350 to 450° F., the over-all quenching speed is markedly increased but rapid circulation has less influence.

Mr. Gilliland warns that quenchometer readings of salt baths are not to be equated with those of oil or water quench baths. As he states it, "The completely dissimilar nature of these mediums, particularly the absence of a vapor blanket in molten-salt quenching, makes valid comparisons possible only by means of hardness-distance data with standard steels". Consequently this has been done. At a constant agitation of 120 ft. per min., a bar of A.I.S.I.-S.A.E. 1046 (⅞ in. diameter by 3 in. long) was quenched in (*a*) fast oil – Rockwell C-60; (*b*) salt plus water – Rockwell C-57; (*c*) medium oil – Rockwell C-54; (*d*) slow oil – Rockwell C-43; and (*e*) dry salt – Rockwell C-32. (All hardness readings were taken on surfaces.) Judging from these tests, it appears that salt baths containing a small amount of water have a quenching power between those of fast and medium oils.



QUENCHING POWER OF SALT BATHS
Water Increases Quenching Rate Obtained in Nitrate-Nitrite Baths

Though the ultimate selection of a quenchant will still depend upon chemical composition and transformation characteristics of the steel, part geometry, and allowable distortion in quenching, Mr. Gilliland feels that, "This information on the quenching ability of salt will guide us in the selection of the most suitable quenchant, particularly for marginal steels and complicated parts".

Large Electron-Beam Furnace Refines Refractory Metals

The ductility and fabricability of refractory metals depend to a large extent on the level of impurities that can be obtained. Recognizing this fact, Haynes Stellite Co., Kokomo, Ind., recently installed a 300-kw. electron-beam furnace for melting columbium, tantalum, vanadium, and other high-temperature alloys. During double remelting at pressures of less than 0.1 micron, impurities are volatilized and the resulting ingots – up to 8 in. diameter by 42 in. long – will contain a maximum of 30 ppm. oxygen, nitrogen and carbon.

The attractive combination of fabricating characteristics and mechanical properties which can be obtained when the furnace is employed is demonstrated by tests on a new columbuim alloying con-

Technical NEWS In Brief

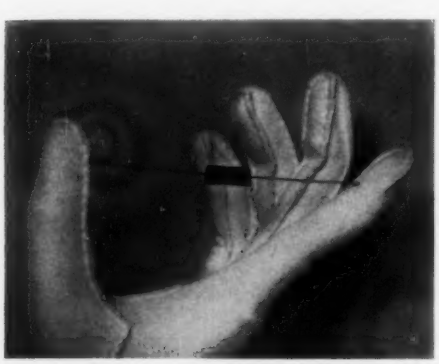
taining 10% W and 5% Zr. At 2400° F. the tensile strength of this alloy, designated Cb-752, is 25,000 psi. and the alloy is not embrittled on heating to higher temperatures. It can be rolled down to 0.005 in., and 0.040-in. sheet can be cold-bent 180° without cracking. The alloy is easily welded and weld ductility during bending is good.

Computer Controls Production of Carbon Resistors

A.S.M. trustee, A. R. Fairchild, had a significant part in developing a technique for applying a thin film of gold to the ends of deposited-carbon resistors that are made in an automatic line. Controlled by a computer, the line consists of 11 machine stations plus a computer and control cabinets. It turns out up to 1200 resistors per hour at the North Carolina Works of Western Electric Co., Winston-Salem, N.C.

Unique feature of the process is a digital control computer which schedules and programs the work, analyzes data and applies statistical tests to determine if a trend is developing. In addition, the computer calculates new setup information for the appropriate station should the analysis indicate deviation from accepted manufacturing tolerances.

This complex equipment controls the production of carbon resistors that begin as tiny ceramic cores and travel one by one through the automatic line. Each core is coated with carbon, gold contacts are applied by a sputtering process performed in argon that deposits a film ten millionths of an inch thick to each end, lead wires are attached, resistance is adjusted in a helixing machine by cutting a spiral groove in the carbon film, and the resistor is encapsulated in epoxy.



DEPOSITED-CARBON RESISTOR
Computor-Controlled Line Produces Up to 1200 Every Hour

From Here and There

Control of smoke and fume has been put under automatic control of U. S. Steel Corporation's Geneva Plant in Utah. Over 95% of all dust and fume particles are removed from stack gases of ten open-hearth furnaces (annual capacity: 2,300,000 net tons) by electrical precipitators built by Research-Cottrell, Inc., Bound Brook, N.J. The automatic system makes high-speed adjustments in the electric power to the precipitators as the concentration of the particles in the flue gases changes.

• • •

A single-piece generator rotor for a steam turbine will be forged from a vacuum-cast ingot of nickel-molybdenum-vanadium alloy steel weighing 535,000 lb. Poured by Bethlehem Steel Co., at Bethlehem, Pa., the huge ingot eliminates the need for making the rotor in sections which would then be bolted together.

• • •

Steel sickles on mowing machines last longer and stay sharper if a thin layer of tungsten carbide is fused to the cutting edges. James Monde, president of the American Specialty Co., Stratford, Conn., said that the carbide is applied to the underside of the sickles, and is constantly exposed as the base metal (S.A.E. 4340) wears. This creates a self-sharpening action which extends the cutting time by four to five times before sharpening is needed.

Deforming Metastable Austenite Produces New Strength Levels

Since deformation of metastable austenite was suggested as a promising strengthening mechanism (see *Metal Progress*, August 1954, p. 103 and September 1959, p. 66), much progress has been made in bringing the technique closer to the realm of the practical metals engineer. Recent work in this field will be described next month in *Metal Progress*. New data will be presented which demonstrate the advantage of deforming certain alloy steels within the time-temperature region defined by the "bay" of the T-T-T curve. The article will show, for example, that modified H11 tool steel can achieve a yield strength of over 350,000 psi. along with an elongation of about 8%.

Why shout?

We don't make fancy claims, just good electrodes. We take great care in making them. We make all kinds, too.

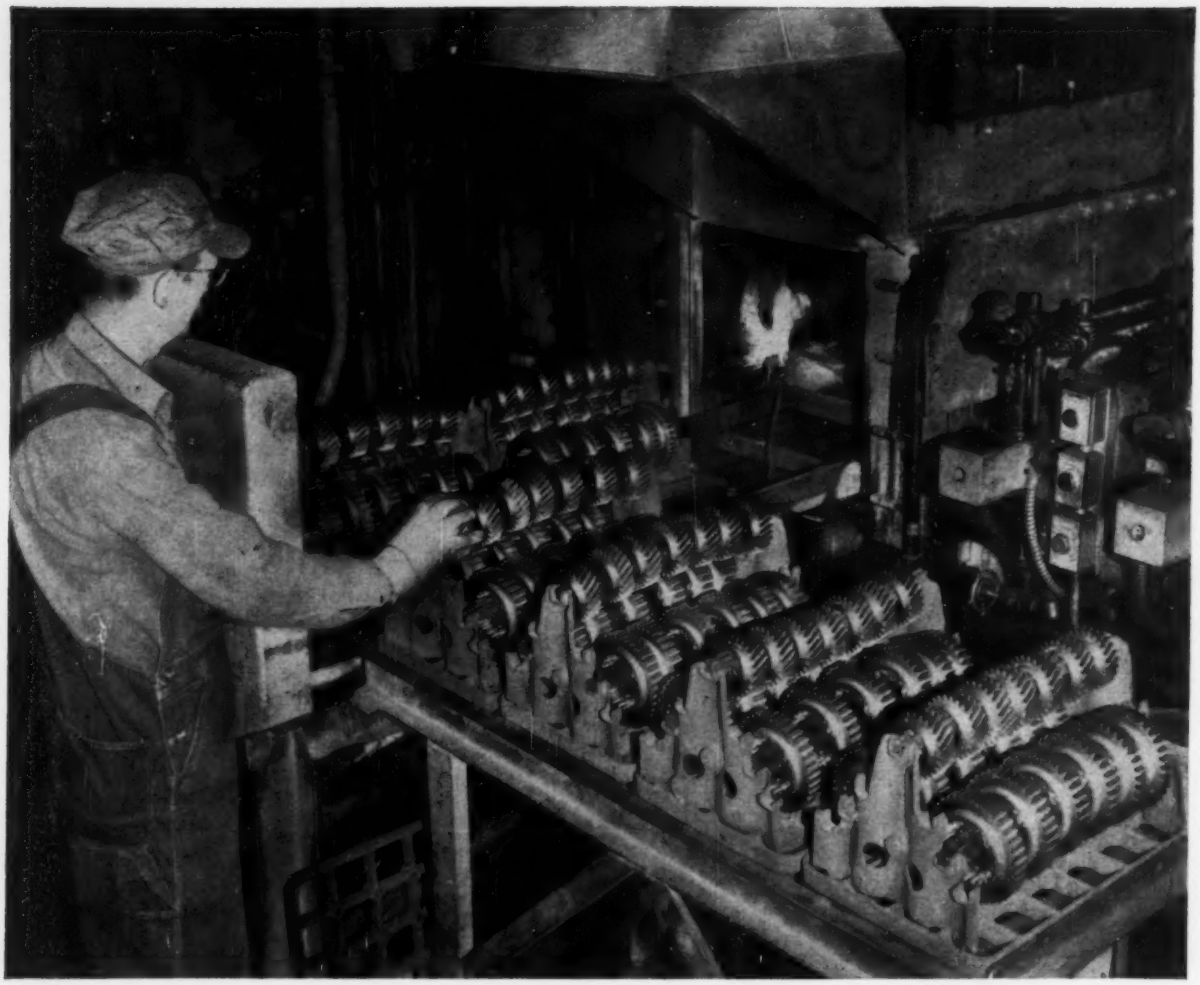
All we ask is that you try a box. We think you'll be pleased with the way they weld. BUT: If they aren't — in your honest opinion — as good or better than any electrode you've used, bring back the box and we'll give you back your money.

Square deal?

HARNISCHFEGER
Milwaukee 46, Wisconsin

P&H
WELDING PRODUCTS DIVISION

Circle 804 on Page 48-E



Cast high-nickel alloy trays and loading fixtures in mass carburizing system handle hot work through treatment. Other high-nickel alloy castings in this furnace include radiant tubes, hearth plates, nails, bracket keys, guides and elevators.

In cycle after cycle...

Cast high-nickel alloy furnace trays withstand 1700°F carburizing atmospheres

Resistance to carburization and thermal shock . . . high-temperature strength and castability make high-nickel alloys ideal for work trays, loading fixtures and other furnace parts.

Truck gears and other parts are mass treated in five carburizing furnaces like the one shown above at a well-known automotive plant.

In cycle after cycle, cast Type HT* high-nickel alloy work trays are used to carry the gears through a carburizing atmosphere of 1650 to 1700°F, through a 400°F oil quench and final cooling at room temperature. Type HT alloy has the hot strength to handle heavy loads and it easily withstands the thermal shocks of this three-stage heat treating cycle.

Type HT alloy is one of four whose high nickel content — over 33% — puts them in a class by themselves for resistance to sustained high temperatures and carburizing furnace atmosphere. You'll do well to specify these high-nickel alloys for your heat treating furnaces.

To help you select the best possible alloy, we offer the new 64-page booklet, "Heat Resistant Castings, Corrosion Resistant Castings...Their Engineering Properties and Applications." You'll find it useful when considering such design factors as sizes, shapes, atmospheres, load or cycling requirements. A post card today will bring you your free copy.

*Alloy Casting Institute designation

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INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Circle 805 on Page 48-B

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS, Metals Park, Novelty, Ohio. Printed by Kable Printing Co., Mt. Morris, Ill.

Subscription $9.00 a year in U. S. and Canada; foreign $15.00. Single copies $1.50; special issues $3.00. Requests for change in address should include *old* address of the subscriber; missing numbers due to "change of address" cannot be replaced. Claims for nondelivery must be made within 60 days of issue. No claims allowed to overseas subscribers. METAL PROGRESS is available on microfilm from University Microfilms, Ann Arbor, Mich.

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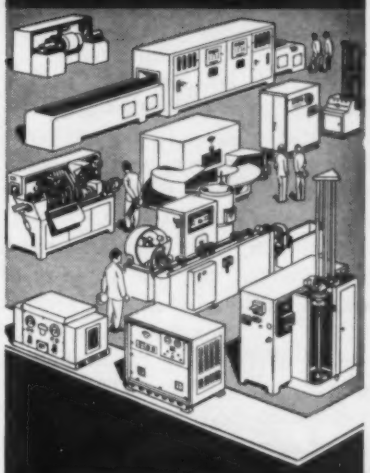

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Subsidiary of Hathaway Instruments, Inc.
Circle 806 on Page 48-B

A fresh approach to metal cleaning

Metal parts and assemblies which have undergone machining, grinding, heat treating, forging or press drawing operations usually have to be cleaned prior to the next processing step or final packaging.

A cleaning compound is selected according to the type of soil, its stubbornness and whether the surface has to be chemically clean—as required if plating or enameling are to follow.

Since the development of surface active agents it has been found unnecessary in intra-operation cleaning to use a harsh alkali. Today's metal cleaning compounds seldom contain free caustic, yet they are far more effective than the earlier materials. By combining detergents with mild alkalies there are definite advantages of easier rinsing, better soil dispersion and emulsification, plus minimum resoiling from a used bath.

Excessive heat unnecessary

Temperatures can be lower, too, hence easier on the operators. The same modern cleaner which will remove light soil at room temperature will be more effective at 120°-140°, but it need not be raised to the boiling point, with resultant fumes, steaming and discomfort.

The detergents used in these modern cleaning formulations for use in power washers are non-foaming, therefore do not interfere with maximum spray impinging force which helps dislodge adhering soil.

Rust protection built in

Another modern trend in cleaning compounds is to add a water-soluble rust preventive, to protect against early rusting by leaving a very slight film on the metal—one which does not interfere with subsequent operations. Of course, this is not possible

Determining the concentration of a cleaning bath and its rate of exhaustion is one of the puzzlers for many a metalworking plant. To be accurate, a chemical titration is more dependable than short-cut "gadgets" sometimes offered. The Houghton technical staff man uses this kit for exact measurement of the strength of a solution. Description or demonstration is available to our customers upon request.

One more improvement in today's cleaners is the property of water softening. These newer products contain sequestering or chelating agents which combine with hard water constituents, holding them in solution and preventing precipitation on the work or in the rinse tank.

This ability of today's metal cleaners to lower surface tension, to protect against early rusting and to soften hard water has resulted in industry's taking a new look at their cleaning practices. Fewer varieties are required because a single cleaner will do a far wider range of work than could the old style free-caustic varieties.

Houghton's new approach to cleaning is typified by our Cerfa-Kleen line of soak tank and power washer compounds—both for cold and hot solutions. If you need a plater's cleaner, or one for removal of inorganic soil, or an acid type, we have those too. **Write E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa.**

Houghton

INDUSTRY'S PARTNER IN PRODUCTION

Circle 807 on Page 48-B

THE RESEARCH STORY BEHIND THIS AD

ZINC

—Chosen By Process Of Elimination

Which car is more rust resistant?
ours
14 others
Special zinc coating protects body parts against corrosion in the 1961 Ford Family of Fine Cars
Ford Motor Company builds better bodies
FORD · FALCON · THUNDERBIRD · COMET · MERCURY · LINCOLN CONTINENTAL

FORD TESTED

A — ORGANIC COATINGS
1. Primers (Solvent Base and Water Emulsion Base)
2. Metallic Rich Paints
3. Plastic Coatings
4. Self Foaming Materials
5. Greases, Waxes, etc.

B — STEEL ALLOYS
1. Stainless Steel
2. Special Alloys

C — MORE UNUSUAL METHODS
(Such as vapor phase inhibitors, irradiated steels, forced ventilation, etc.)

D — METALLIC COATINGS
1. Aluminum Clad
2. Terne Plate
3. Tin Plate
4. Cadmium Plate
5. Zinc Coated
   A. Electrogalvanized
   B. Hot Dipped

Reprints of an extensive report on the Ford research program which culminated in their choice of Zinc are available on request from St. Joe.

The search for the best defense against corrosion was a major project with Ford Motor Company. A long and painstaking series of laboratory, road and production tests were scientifically conducted and evaluated before Ford named the winner—*galvanized steel.*

FORD EVALUATED THEM FOR

1. Corrosion Protection
2. Formability
3. Weldability
4. Painting
5. Method Employed (special requirements in applying, inspection, etc.)
6. Stock (and scrap) handling problems, if any
7. Cost

Corrosion-Protection Is A Job For ZINC

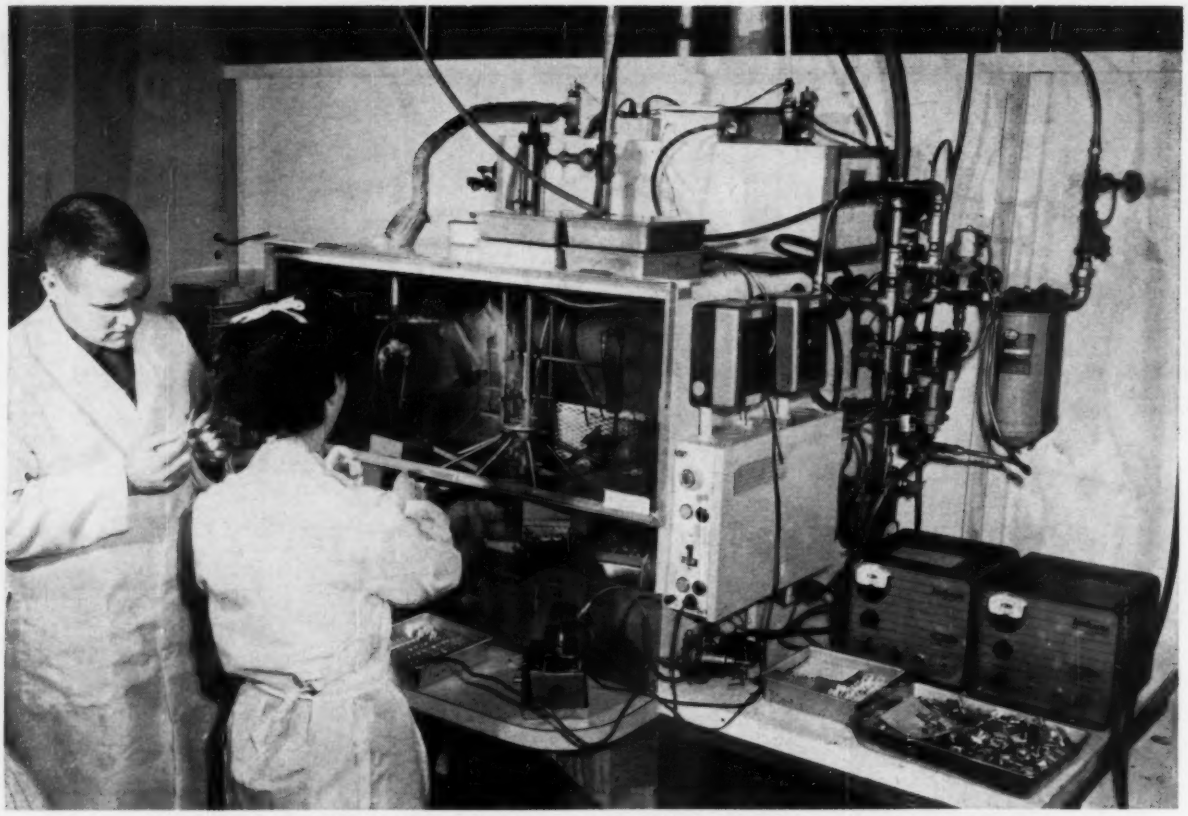
—AND THE ZINC FOR THE JOB

ST. JOSEPH LEAD COMPANY ST. JOE

250 PARK AVENUE NEW YORK 17, N.Y.

ZN-102

Circle 808 on Page 48-B



Charles Parke, production engineer at the Potter and Brumfield plant, a division of American Machine and Foundry Company, spot checks a part while operator removes remaining components from the cleaning system.

"WE MAGNIFY EACH PART 10 TIMES . . . DON'T FIND GREASE AFTER A NIALK® TRICHLOR BATH"

Workers handle delicate microminiature relays with utmost care in Potter and Brumfield's "white room." Yet some contamination with dust and grease is inevitable.

"We assume everything is contaminated," continues Charles Parke, production engineer—and orders all of the minute parts cleaned with Nialk TRICHLORethylene.

100,000 parts between cleanouts.

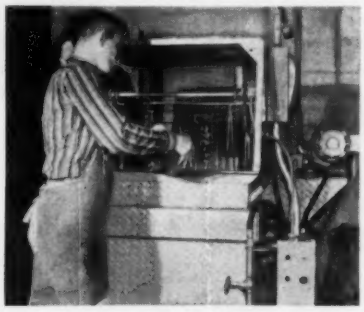
According to C. R. Stone, Director of Production, Nialk Trichlor removes the last bit of film on the metals. Potter and Brumfield degreases magnetic iron and nickel silver, running about 100,000 parts through between cleanouts.

They tried another vapor degreasing solvent, but "it didn't do the job Nialk Trichlor does. It wasn't distilling right and it wasn't doing the cleaning job."

Though much metal goes through every degreasing bath, this company doesn't have to titrate or run other tests.

Flush and vapor degrease—one trichlor

Potter and Brumfield uses one grade of trichlor for both flushing and vapor degreasing, considers this an important benefit.



And Mr. Stone concludes, "Hooker should get a large share of credit for the quality of parts produced by Potter and Brumfield."

You can get the same dependable cleaning with nonflammable Nialk TRICHLORethylene.

Hooker technical experts will help you set up your system. Then they'll check back with you regularly to make sure your flushing or degreasing operation stays trouble-free.

Talk to your Hooker Chemical distributor. He'll gladly help you with your problems and questions.

Or write us direct. We have years of experience to put at your disposal.

HOOKER CHEMICAL CORPORATION

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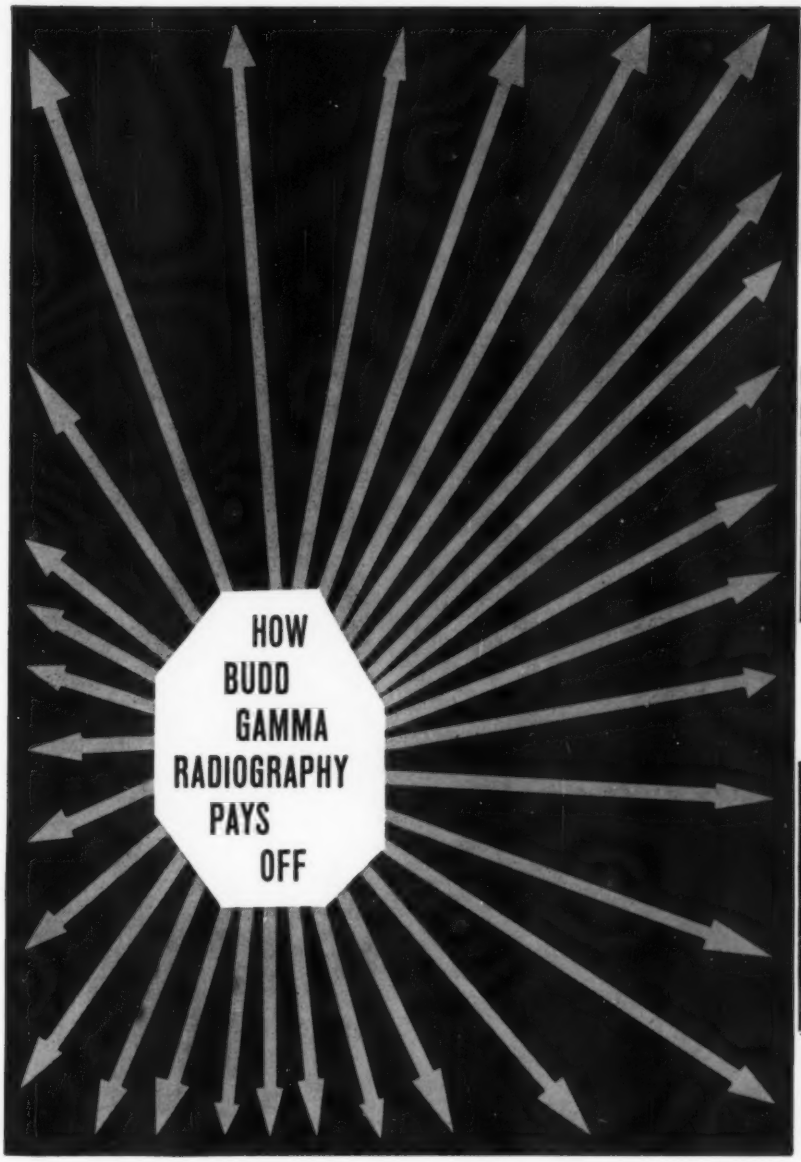
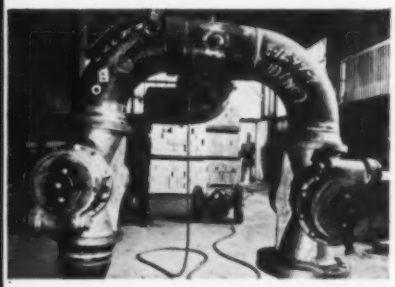


At Kaiser Steel Corporation's Fabricating Division, a lightweight, easily-carried Model 30 Iriditron simplifies checking plate welds in the bow section of this steel barge, in outdoor inspection areas.

At Pacific Southern Foundries, Inc., a subsidiary of Pacific Valves, Inc., a powerful 1000-curie Model 1061 Multitron quickly radiographs large pieces like this steel valve casting. Unit features fully automatic fail-safe protection and remote operation from a console control center.



At a large pipe and metal fabricating shop, a Model 50 Multitron radiographs . . . in just one exposure . . . the entire circumference of a 360° weldment at the Tee fitting of this pipe assembly. Featuring remote control and complete mobility, the Model 50 goes right to the job anywhere in the shop.

Budd gamma radiography equipment is used today throughout the free world to bring speed, economy and mobility to the inspection of castings and forgings . . . steel and steel plate products . . . machinery and large machine parts . . . solid fuels for rockets and missiles . . . beams, piers and other structural units . . . pipe, pressure vessel and fabricated structure weldments . . . wrought metal items . . . a host of other products. One of the 21 *standard* Budd Iriditron and Multitron models will probably fit your exact requirements. Write or call for our Gamma Radiography Bulletin, or for a consultation on your needs.

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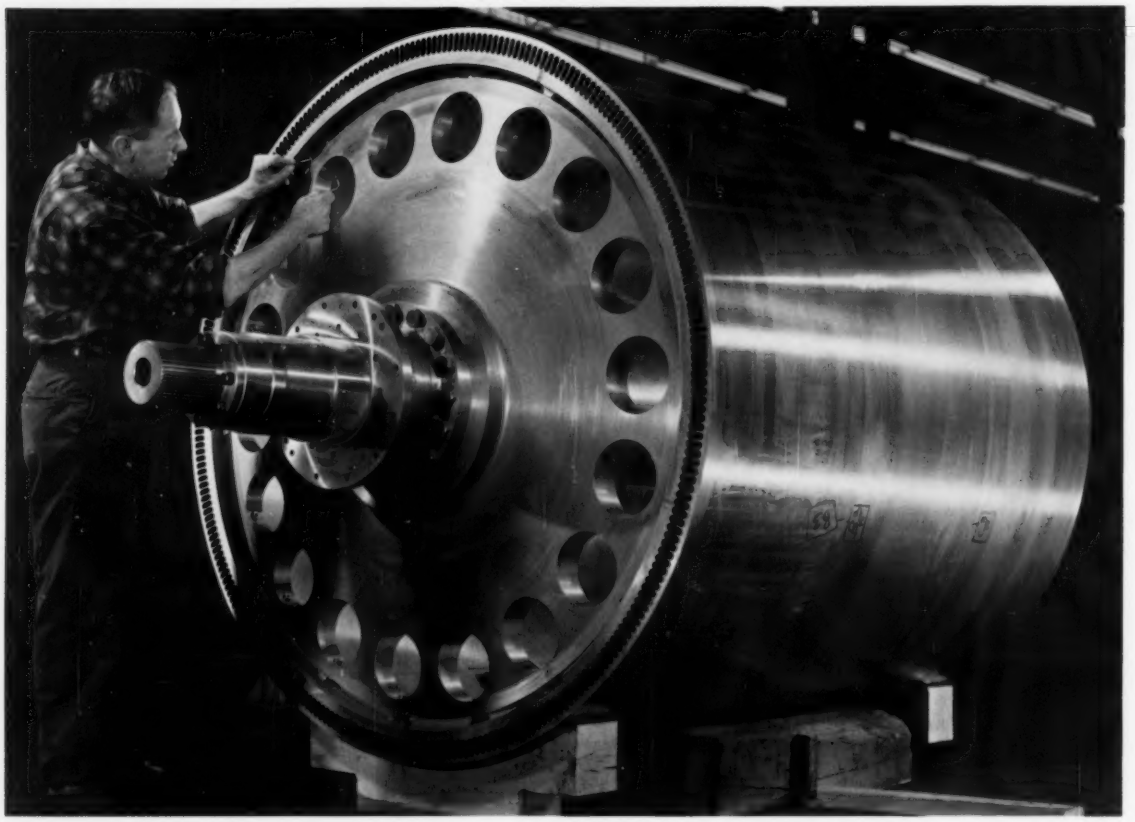
THE BUDD COMPANY • P.O. Box 245 • Phoenixville, Pa.

Consult your phone book for sales offices in: Atlanta, Ga.; Chicago, Ill.; Dallas, Tex.; Los Angeles, Calif.
In Canada: Budd Instruments, Ltd., 170 Donway West, Don Mills, Ont.

Circle 810 on Page 48-E

Rough-machined ring and forged ring being sawed at our Homestead Works.
Three-ring rotor, showing rectangular holes through ring wall, with end plates and tubular spindle assembled into a unit ready to ship.



How to bring a missile back through temperatures to 8,500°F

You can broil a steak at 350°F. Pure iron melts at 2795°F. Most meteorites burn up when they enter the earth's dense atmosphere. Today, man is firing missiles to meteoric altitudes—but the problems of tolerating the extreme temperatures of re-entry have been the greatest challenge to his ingenuity.

One of the major obstacles to simulating re-entry conditions was how to produce for realistic time durations pure air in large volumes at meaningful temperatures, pressures and velocities. This problem is being solved with the *Wave Superheater*—an innovation in hypersonic wind tunnels. Temperatures to 8500°F, pressures to 200 atmospheres and velocities up to Mach 15 can be attained with this facility. Cornell Aeronautical Laboratory has devised this equipment to test full-scale missile components in the laboratory.

The wave superheater is essentially a blow down system using a rotor with 288 tubes (passages) drilled into its periphery. The shock tubes are charged with air; then a driver gas (helium) at a pressure of 1500 psi is released through one end of each tube, successively superheating by shock waves the air which is then collected and expanded into the wind tunnel. The rotor operates at a maximum temperature of 800°F; each tube is momentarily cooled as it rotates, to be ready for the next charge.

Rotor Ring Forgings. The heart of the superheater is the rotor made from three USS Stainless W forgings. The rough-machined rings are each 63" OD, 54" ID, 23½" long and weigh 6,000 pounds each. USS Stainless W was chosen for this demanding application because of its precipitation hardening characteristics, and its ability to retain the required high strength at the operating temperature.

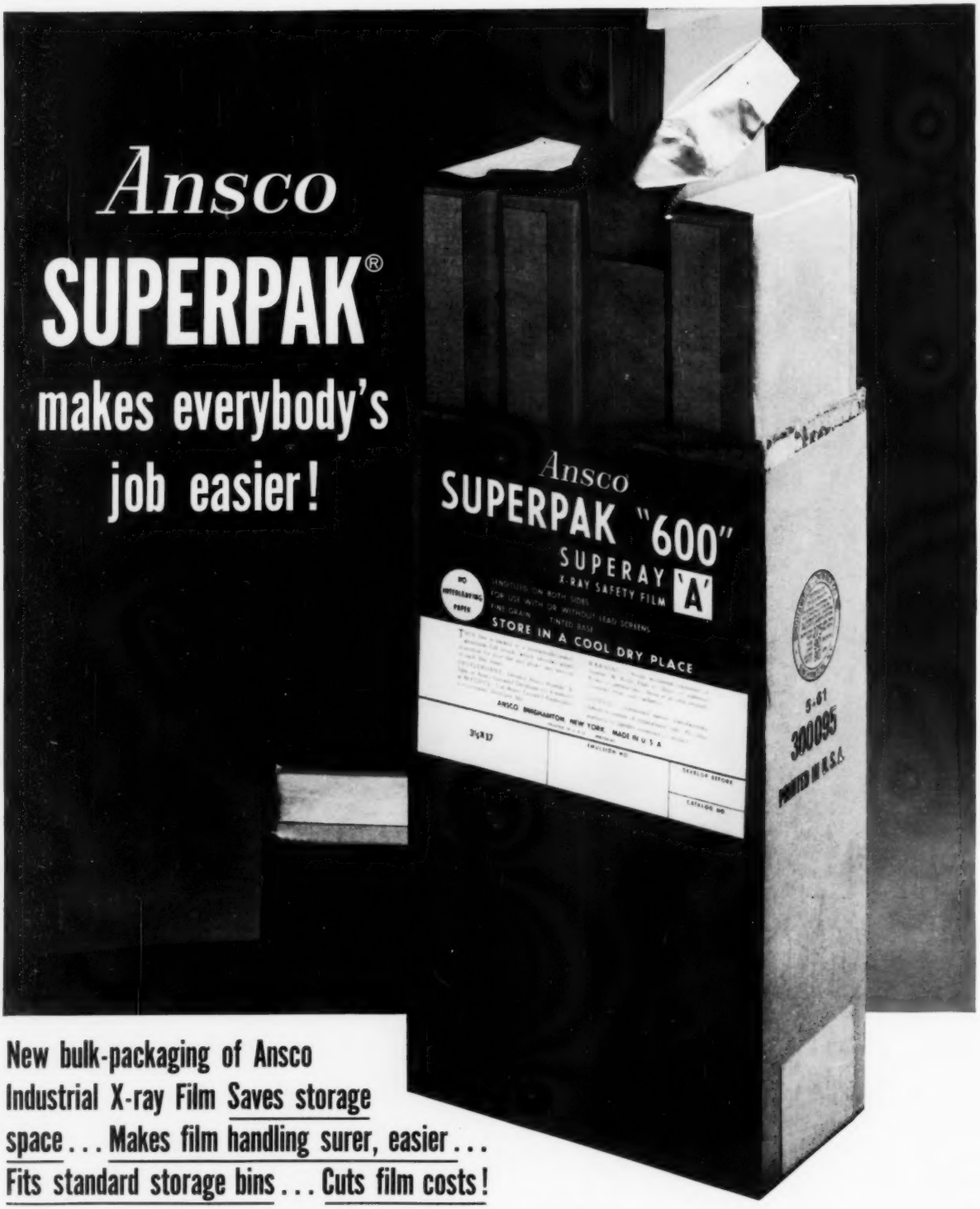
The three rings were obtained from a 59" diameter ingot, which was cogged, sheared, upset-forged, punched and finally mandrel-forged under our 10,000-ton press. After rough machining and completing the inspections called for, the rings were shipped to 20th Century Machine Tool Company, Utica, Michigan, who drilled and broached the holes seen in the assembled view of the three-ring rotor. With an assist by Hoover Tool & Die Company, Warren, Michigan, the final machining and assembly was completed in 10 months.

No matter what kind or size of USS Quality Forgings you need, you get the advantages of the finest steel, the most modern equipment and the most skilled forging men in the world. Address inquiries to United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania. A copy of our booklet "USS Nuclear Forgings" may be secured by writing to the same address. USS is a registered trademark.

United States Steel Corporation · Columbia-Geneva Steel Division · Tennessee Coal and Iron Division · United States Steel Export Company

USS TRADEMARK **United States Steel**

55555-2



New bulk-packaging of Ansco Industrial X-ray Film Saves storage space... Makes film handling surer, easier... Fits standard storage bins... Cuts film costs!

Two forms of the new Superpak package are available to Ansco Industrial X-ray film users. Illustrated here in the popular 3½ x 17 inch size. Both the Superpak '300' and Superpak '600' shipping cartons have the same outside dimensions. In the '300' package, each of the four inner cartons contains 75 sheets of film packed *with interleaving paper*. In the '600' package, each inner carton contains *twice* as much film—150 sheets—packed *without* interleaving paper.

Both packages bring the dependable performance of Ansco Industrial X-ray films to the industrial user in a more convenient and economical form. Ansco, Binghamton, N. Y.

Ansco

X-ray

Circle 811 on Page 48-B

CASTINGS FOR HIGH
TEMPERATURE SERVICE
FAHRITE
HEAT AND CORROSION
Alloys
Fahrite alloy castings have high tensile strength, high resistance to thermal shock and stand up longer in service. There are grades of Fahrite to meet your exact operating conditions.
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THE OHIO STEEL FOUNDRY CO.
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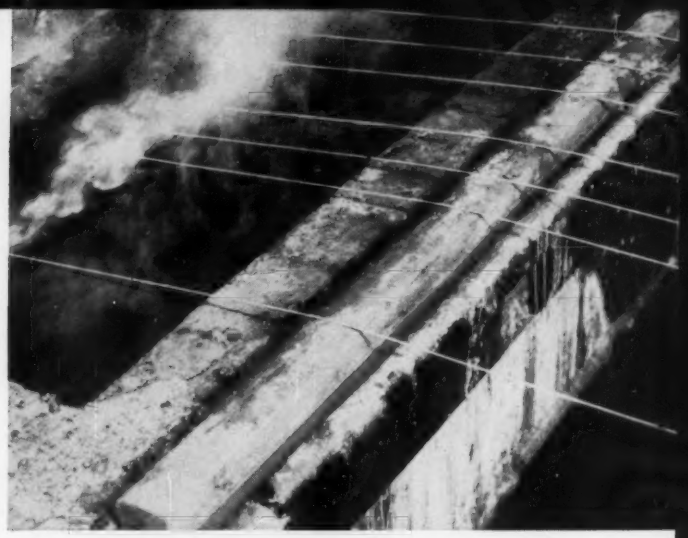
Plants at Springfield and Lima, Ohio

Circle 812 on Page 48-B

Report from Carborundum:

6 ways to do jobs better with refractory materials



HANDLING MATERIALS IN ACID SOLUTIONS:

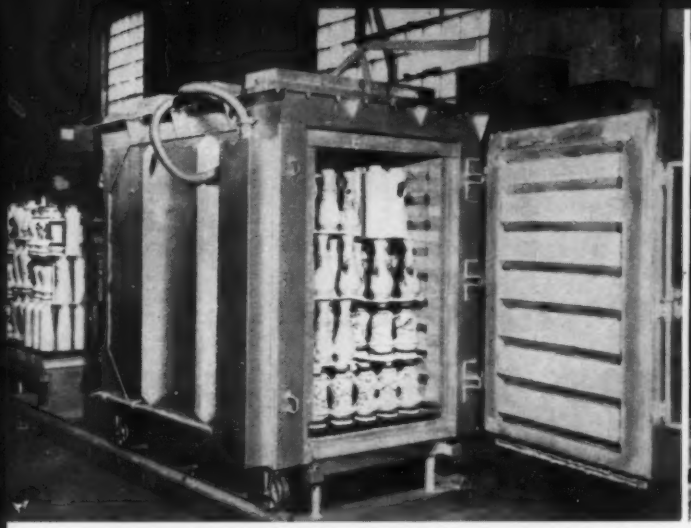
SILICON CARBIDE WEAR BLOCKS RESIST CORROSION AND ABRASION. Steel wire moving at 100 ft/min passes over CARBOFRAX® silicon carbide wear blocks to a pickling tank in the photo above. A 15% solution of sulfuric acid at 400 F is used. Sinker blocks are also of CARBOFRAX silicon carbide. Despite the action of the acid and the abrasion of the wire, the silicon carbide shows no wear after months of service. Similar applications involving Carborundum refractories are found in aluminizing and other wire coating baths.

SKID RAILS IN REHEAT FURNACE:

SILICON CARBIDE RAILS LAST 30 TIMES AS LONG AS STEEL IN HIGH TEMPERATURE, ABRASIVE SERVICE. The 6¾" x 8" brass billets seen in the picture are pushed through a 38-foot long gas-fired extrusion mill furnace. Steel skid rails required replacement every five weeks. When CARBOFRAX silicon carbide rails were installed, 156 weeks of service were obtained. Reduction in downtime resulted in lower operating costs and higher production rates. Superior wear resistance and ability to withstand high temperatures make silicon carbide a profitable choice for applications like this.

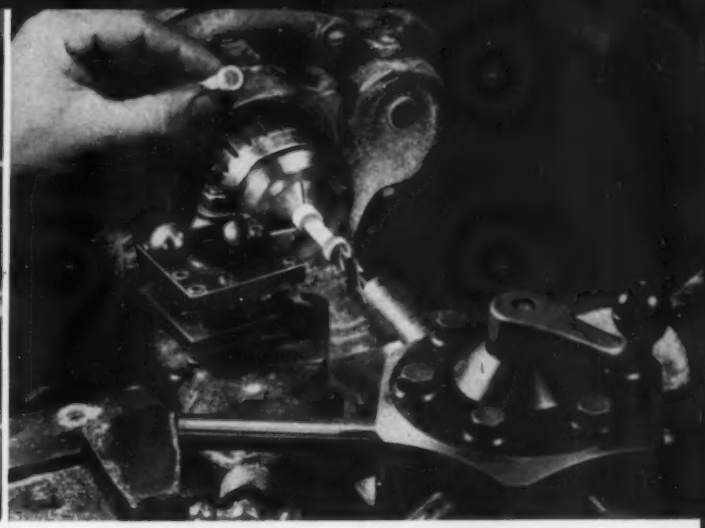
LONGER LIFE FOR BURNER RINGS:

SILICON CARBIDE CONSTRUCTION WITHSTANDS FLAME EROSION AND HIGH TEMPERATURES. Refractory burner rings in pulverized coal-fired boiler frequently fail fast because of the abrasive action of the fuel particles and thermal shock due to intermittent operation. Many users have found an answer to the problem in CARBOFRAX silicon carbide rings. Silicon carbide is not only superhard, but also stays hard at high temperatures. High thermal conductivity and resistance to thermal shock minimizes cracking and spalling. Flame patterns are maintained.



DIRT-FREE OPEN FIRING WITH MOVABLE KILN:

FIBERFRAX® CERAMIC FIBER LINING REPLACES BRICK: MAKES POSSIBLE TEMPERATURES UP TO 2200 F. The interesting movable kiln illustrated is made by Unique Kiln Co., Hillsdale, N. J. It moves on rails to enclose a stationary loading bed. Two beds can be serviced alternately. Door and hood linings of Carborundum's light-weight FIBERFRAX ceramic fiber, in block form, eliminate the problem of dislodged dirt and dust encountered with fireclay type refractories, which often damage ware being fired. High heat resistance and insulating properties of FIBERFRAX fiber make possible firing up to 2200 F.

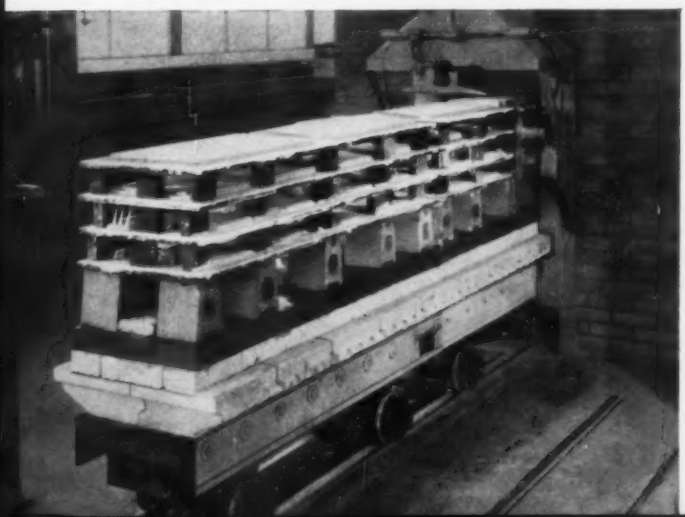


SHAPES AND JIGS MACHINED FROM CERAMIC:

BORON NITRIDE IS EASILY MACHINED; RESISTS HIGH TEMPERATURES AND CORROSION. The photo shows the machining of a semi-conductor jig from Boron Nitride, a self-bonded material made by Carborundum. Close tolerances, high surface finish and intricate detail are possible. Boron Nitride offers advantages in semi-conductor production compared with graphite jigs, yields from which often drop 40% after only 50 cycles. The material also offers possibilities for insulating tubes and shapes; chemical equipment parts, crucibles, brazing fixtures, gaskets and seals. Shapes withstand furnace temperature of 3000 F; powder as high as 5400 F.

ELIMINATING CRACKING IN KILN CAR TOPS:

COMBINATION OF REFRACTORIES SOLVES PROBLEM IN CERAMIC INDUSTRY. Used in a gas-fired electrical porcelain kiln, the cars illustrated have been in service for more than two years at cycles of 14 to 15 hours, operating from cold to 2290 F to cold. Car top cracking due to heat shock has been eliminated by use of three different Carborundum refractories—a bottom layer of MULLFRAX® electric furnace mullite for high load carrying capacity, a middle course of ALFRAX® alumina "bubble" brick for insulation and an upper course of CARBOFRAX silicon carbide tile for resistance to thermal shock.



Want help on your problems?

Carborundum engineers will be glad to recommend refractories to answer your specific needs. For information, contact Dept. M-81, Refractories Division, Carborundum Co., Perth Amboy, N. J. Descriptive brochures available on request. Please specify the area or areas of particular interest to you.

for engineered refractories...count on

CARBORUNDUM®

Circle 813 on Page 48-B

Riehle

...universal testing machines

WITH A FUTURE

RIEHLE 120,000 lb. Universal Hydraulic Testing Machine

RIEHLE offers complete instrumentation and accessories for testing materials over a wide range of temperatures. This includes vacuum furnaces for tests up to 5000°F., cryostats for tests down to 4°K., a full range of specimen holders and tools, automatic strain rate and load rate controls and load cells.

RIEHLE offers sensitive, rapid response testing machines in both screw power and hydraulic types in capacities from 2,000 to 450,000 lbs.

RIEHLE Electro-Balanced Indicating Unit—the most versatile, accurate indicating system on the market—is available for both types of testing machines.

RIEHLE Testing Machines are floor-mounted . . . no special foundation required.

RIEHLE combines ruggedness and sustained accuracy with inherent long, trouble-free service by using the most advanced methods in modern engineering technology and fabricating practices.

RIEHLE maintains a national field calibration service for complete and dependable certified inspection and calibration.

RIEHLE engineers often save project time, capital investment and labor costs by recommending testing procedures and equipment to meet specific requirements. Write for Bulletin RU-2-60. Address Dept. MP-861.

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RIEHLE also builds Creep and Stress-Rupture Testing Machines, Hydraulic Fatigue Testing Machines, Construction Materials, Impact, Brinell, Torsion, Horizontal Chain, Rope and Cable Testers and Portable Hardness Testers for Rockwell Readings.

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Circle 814 on Page 48-B

NEW PRODUCTS

Foundry Degassing Unit

A "Foundry Degasser" made by *F. J. Stokes Corp.* provides a simple and practical means of removing entrapped gases from molten metal before casting. The unit, which can accommodate crucibles up to 150 lb. in size, consists of a vacuum chamber with a quick-opening cover, and a pumping system capable of evacuating the chamber in a minimum of time. The procedure for degassing a melt is simple: A crucible is lowered into the chamber, the cover is swung into place and in 5 to 10 min. most of the entrapped oxygen, hydrogen, and nitrogen has been eliminated. In addition, the rapid churning action flushes dross to the surface. Degassed metal yields cleaner, denser, stronger castings, low in porosity and voids.

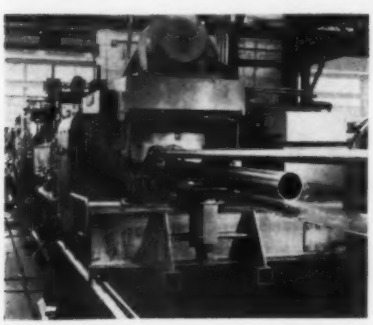
For further information circle No. 540 on literature request card, p. 48B

Steel

Welded Steel Tubing

The addition of more than 400 new sizes and gages to its line of round, square, and rectangular tubing permits *Republic Steel Corp.* to offer carbon steel rounds up to 6 in. O.D. with a 0.250-in. wall; squares up to 5 in. with a 0.250-in. wall; and rectangular sizes with peripheries up to 20 in. The tubing conforms to Republic's ST-101 specification covering resistance welded carbon steel tubing for structural use: 33,000 psi. (min.) for grade A round tube; 42,000 and 50,000 for grade B and C, respectively; for shapes, yield strengths are 33,000, 45,000, and 55,000 psi. Minimum sizes are ⅜ in. O.D. in 22-gage rounds, ¼ by ¼ in. squares in 22-gage; and ¼ by ⅜ in. rectangular tubes in 22-gage. Tubing is available in carbon grades ranging from A.I.S.I. 1008 to 1040.

For further information circle No. 541 on literature request card, p. 48B



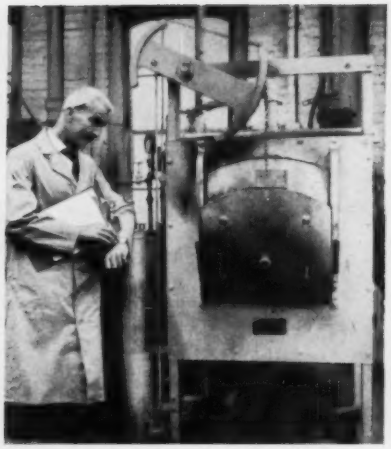
Tooling

Reinforced Grinding Wheel

Designed for weld grinding and light snagging, this wheel combines the advantages of a saucer shape with the convenience of a throwaway mount. Available in 7 and 9-in. sizes to fit standard portable grinding

NEW TOOL STEEL SERVICE

reduces heat treating costs



The man who heat treats many different tools . . .

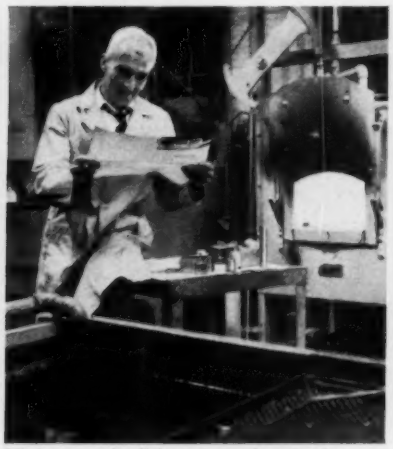
can realize major savings with Crucible's new Tool Steel Service.

He'll operate his furnaces more efficiently and profitably because

he'll now be able to heat treat many more tools at one time.

He'll know exactly how each grade responds to heat treating.

—so he'll certainly get more consistent results by employing time-tested techniques.



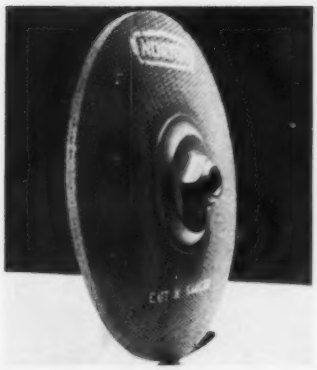
All by standardizing on a few basic tool steel grades!

To find out how this new Tool Steel Service can cut your heat treating costs, call in a CRUCIBLE Service Engineer.

CRUCIBLE STEEL COMPANY OF AMERICA

Branch Offices and Warehouses: Atlanta • Baltimore • Boston • Buffalo • Caldwell, N. J. • Charlotte • Chicago • Cincinnati • Cleveland • Columbus • Dallas Denver • Detroit • Erie, Pa. • Grand Rapids • Houston • Indianapolis • Los Angeles • Miami • Milwaukee • Minneapolis • New Haven • New York • Philadelphia Pittsburgh • Portland, Ore. • Providence • Rockford • Salt Lake City • San Francisco • Seattle • Springfield, Mass. • St. Louis • E. Syracuse • Tampa • Toledo • Tulsa
CRUCIBLE STEEL OF CANADA, LTD., SOREL, QUEBEC, CANADA

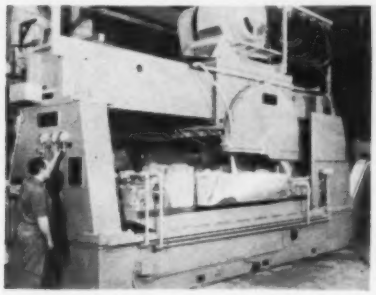
Circle 815 on Page 49-B



equipment, the "Cut-N-Saucer" wheel permits the operator to get closer to the work – this means easier control and less operator fatigue. *Norton Co.*
For further information circle No. 542 on literature request card, p. 48B

Automatic Circular Saw

Aluminum alloy billets and slabs up to the largest sizes produced – 36 in. diameter or 20 by 80-in. slabs – can be cut to close length tolerances with a 100-in. diameter circular saw made by *Loma Machine Mfg. Co.*



Driven by a 200-hp. two-speed motor (3000 or 6000-ft. per min. cutting speed), the machine features an overhead sliding carriage design. The hydraulic feed provides variable cutting rates up to 2 in. per sec. A unique safety feature makes the saw virtually jam-proof.
For further information circle No. 543 on literature request card, p. 48B

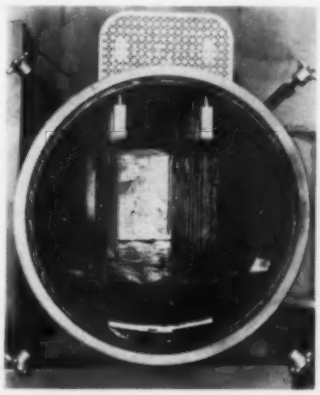
Heating

Noble Metal Thermocouple

In response to demands for a thermocouple material with an emf. equal to Chromel-Alumel, plus stability over an extended temperature range, *Englehard Industries, Inc.* has developed a noble metal couple called "Platinel". After testing for 2500 hr. at 1300° C. in jet engines and nuclear reactors, a drift of only two degrees (emf. output) was found. The thermocouple wire, obtainable in all standard sizes, is designated Platinel 1786 for the positive leg (an alloy of gold, palladium, and platinum) and Platinel 1503 for the negative leg (gold and palladium).
For further information circle No. 544 on literature request card, p. 48B

Cold-Wall Vacuum Furnace

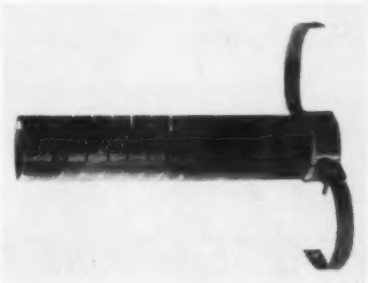
Designed for materials research, development, and production programs in the electronics, space and nuclear fields, a line of vacuum furnaces from *Vacuum Specialties, Inc.* can produce temperatures up to



2500° C. (4500° F.) at 1×10^{-5} mm. Hg. The units, which range in size from 60 to 2700 cu. in., employ a series of double-hairpin-shaped refractory metal rods, attached to quick-acting, water-cooled connectors. The heat shields, made of thin dimpled refractory metal sheets, are easily removed for cleaning and replacement.
For further information circle No. 545 on literature request card, p. 48B

Double Spiral Heating Elements

The "Type DM" element, a hollow silicon carbide tube up to 3 in. in diameter, is made with a double spiral hot zone and has both electrical connections at one end. Ideally suited for use in laboratory crucible furnaces,



W. C. "Bill" Pine, our chief metallurgist says . . .

production-proved LAC-200 Series furnaces pay dividends on precision

BRAZING

Talk about controlled heat . . . easy operation . . . versatility . . . economy — and you're describing a Hayes Model LAC-200 Series Conveyor Brazing Furnace.

MULTI-ZONE HEAT CONTROL permits exact settings of temperature profiles — for quality work on each brazing, alloying, metal bonding or soldering cycle. When working with parts of unequal section, a pre-heat zone insures stabilized heat throughout the mass.

CONSTRUCTION MATCHES THE JOB. If an exothermic atmosphere is to be used, open chamber construction reduces equipment cost. For more refined atmospheres, muffles are available, which provide a baffling action to prevent creeping of temperature profiles.

WORK HANDLING IS EASIER, too, with a Hayes Model LAC-200 Series Furnace. Loading tables combine with constant belt feed to make this a remarkably high-production unit, per dollar cost and per foot of floor space.

VERSATILITY COUNTS. While designed for brazing, your Hayes furnace can double for annealing, hardening, and other heat treat operations. It's a bull for work!

WHATEVER YOUR BRAZING NEED — from silver (1100°F range) to platinum (3400°F range with type M-Y or Vacuum Furnaces), Hayes know-how in equipment and engineering can come up with a RESULTS GUARANTEED answer . . . tested in our lab. on full-production equipment . . . proven by scores of successful installations in industry. Bulletin 5711A gives LAC details. For your copy, write C. I. Hayes, Inc., 802 Wellington Ave., Cranston 10, Rhode Island.

C. I. HAYES, INC.

Established 1905

It pays to see Hayes for metallurgical guidance, lab. facilities, furnaces, atmosphere generators, gas and liquid dryers, Pow-R-Trol (TM) control units.

Circle 816 on Page 48-B

REMARKABLE NEW PROCESS

...opens way for you to solve critical high-temperature design problems

At 5500°F. cobalt runs like water. Nickel boils. Zinc vaporizes. But tungsten remains solid.

To make this property pay off for you, Sylvania recently put to work its new isostatic pressing and sintering operation. Through this operation, it can produce tungsten or molybdenum ingots up to 10" in diameter and up to 4 feet long. *Sylvania now produces all four*—billets and ingots for forging, electrodes for arc casting, blanks for machining, or machined blanks ready for your use.

Perhaps you've never considered refractory metals as the answer to your needs. But the same properties that solve the problems of throat inserts for rockets and missiles can pay you dividends in piercing points, boring bars, dies, tools and in countless other ways.

Want more facts? Or experienced technical help in proving out your special ideas? Just write Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pennsylvania.

SYLVANIA

Subsidiary of GENERAL TELEPHONE & ELECTRONICS

Circle 817 on Page 48-B

the elements may be mounted vertically, or horizontally with connections at the rear. Should the process demand it, the elements may also be lowered over the work. *Morganite.*

For further information circle No. 546 on literature request card, p. 48B

Multi-Purpose Pyrometer

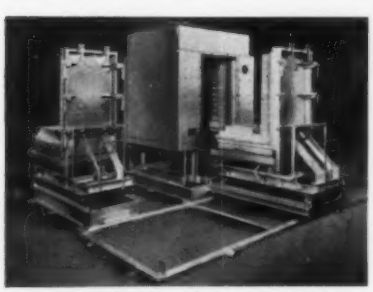
A pyrometer introduced by *Edmund Scientific Co.* can be used with practically all base-metal thermocouples, and also serves as a sensitive millivolt meter. This precision instrument is unaffected by different

lengths of thermocouples because of its high internal resistance. The three scales are: 32 to 2400° F. and 0 to 1370° C. for Chromel-Alumel (Type K) thermocouples; and 0 to 50 millivolts. Conversion tables are included for use with Type J, L, and T thermocouples.

For further information circle No. 547 on literature request card, p. 48B

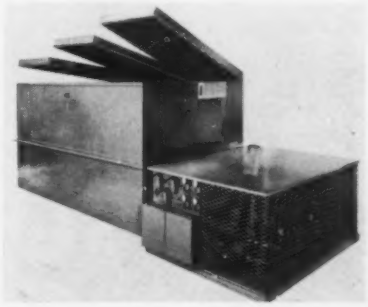
Car-Bottom Kilns

Operating at temperatures up to 2700° F. in air or a controlled atmosphere, this unit is employed in processing abrasives, carbon products, and precision electronic parts such as ferrites and titanites. Two power ranges are available: low-power for standard slow-cycle firing, and high-power for accelerated firing at high temperatures. Normal convection cooling or faster forced cooling is available on both models. *Harper Electric Furnace Corp.*



For further information circle No. 548

Low-Temperature Processing



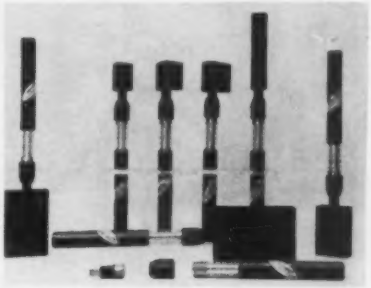
Cincinnati Sub-Zero Products announces a 250 cu. ft. recessed chamber for low-temperature (to −110° F.) metallurgical processing of ferrous and nonferrous materials. The stainless steel chamber, 120 in. long by 60 in. wide by 60 in. deep, will chill one-half ton of steel from ambient to −110° F. in 2 hr. Model 6SR-110-250-R, with a thermal capacity of 12,000 Btu. per hr. at −100° F., features two 16-in. fans for even temperature distribution, and three hydraulically operated lids for full access to the chamber interior.

For further information circle No. 549

Finishing

Selective Plating Anodes

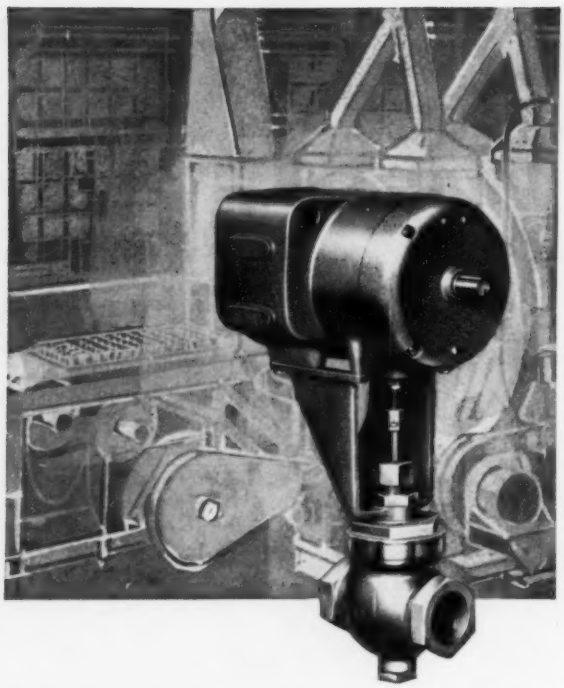
Useful for prototype work, the "Selectron" plating process is an ideal maintenance and repair tool because it often eliminates disassembly and reassembly. Two new plating styluses, half-round and flat, extend the range of application of *Selections, Ltd.*



"table-top" electroplating systems. The flat "SF" anode, available in three sizes up to 3½ by 2½ in., is used in plating large flat or slightly convex surfaces. The "HR" stylus, with one flat and one round surface, is used in plating concave surfaces and hollows. Wrapped in cotton and saturated with

'PSC' RADIANT TUBES in
Any Design or Dimension
'Light-Weight' Heat-Treat Units for Every Use
PSC fabricated tubes furnish four substantial advantages: (1) Light-wall construction saves furnace time and fuel. (2) Return bends are of same wall thickness as tubes, promoting uniform flow of gas. (3) Smooth dense walls minimize carbon build-up and burn-out. (4) Up to 100% longer life. In any alloy, size or type, including parabolics. We repair and remodel radiant tubes, retorts and inner covers – save you money.
PSC
THE PRESSED STEEL CO • Wilkes-Barre, Pa.
PSC

Circle 818 on Page 48-B



OPERATE ANY SLIP STEM OR ROTARY STEM VALVE

OPERATE ALL INDUSTRIAL TYPE DAMPERS

More torque! More precise positioning for industrial valve and damper applications!

New Honeywell Actionator* Heavy-Duty Electrical Control Motors

Use these compact, powerful new industrial motors wherever highly accurate modulating two or three-position control is required.

Some models operate vertical-acting stem valves having lifts of from ½ to 1½ inches. The double-ended shaft can also simultaneously operate rotary stem valves, butterfly valves and other devices through suitable linkages. Other models operate rotary-shaft type valves, dampers, louvers and other final control elements.

ACTIONATOR control motors are available with two or three-position floating or proportional control, and with a variety of speeds from 7.4 to 120 seconds full-stroke operation. Torque ratings range to 200 inch/lbs.

Additional features include built-in linkage and strain relief, a mounting yoke and enclosed terminals with gasketed housing to meet JIC specifications. Also available are models that include cam-operated internally mounted switches for a variety of sequencing switching purposes.

For complete information, call your local Honeywell office. Or write Minneapolis-Honeywell, Dept. MP-8-62. Minneapolis 8, Minnesota. *Sales and service offices in all principal cities of the world.*

*Trademark

Honeywell

First in Control

SINCE 1885

See us in Sweet's 1961 Product Design File, Section 7b-Min.

Circle 819 on Page 48-B

electrolyte, the stylus is brushed over the area to be plated, depositing metal to precisely controlled thicknesses.
For further information circle No. 550

Soak Cleaner for Aluminum

Silicate residues on aluminum are difficult to rinse and interfere with subsequent anodizing, chromating, or bright dipping – leaving visible patterns on the work. A silicate-free alkaline soak cleaner from *Enthone Inc.*, "NS-35", eliminates these troublesome films. The cleaner – a powdered material which is dissolved in water at 2 to 8 oz. per gal. concentration – removes light soil, marking inks, and light buffing compounds. At temperatures below 150° F. it does not etch aluminum; above 150° F., very mild, controlled etching can be accomplished.
For further information circle No. 551

Ultrasonic Cleaner

This two-stage vapor degreaser uses "Freon TF" solvent, recommended for cleaning parts containing metals, plastics, or other materials which would ordinarily be attacked by chlorinated solvents. Parts are placed in the ultrasonic chamber to loosen contamination and then transferred to the Freon vapor chamber; they emerge from the unit completely clean and dry. Available in three sizes, all models are self-distilling, which permits continual re-use of the solvent. *National Ultrasonic Corp.*
For further information circle No. 552

Welding

Weld-Strength Tester

The portable "Model VTA-46" tensile tester evaluates weld joint strengths for applications such as

THESE MIXERS ARE KICKING UP A calculated STORM

If you could see through the wall of this large rectangular tank, you'd think you were looking at a slice of ocean in a hurricane.

Ten 25-hp LIGHTNIN Mixers—five on each side of the tank—are causing all that turbulence. Reason? To quench large gears without cracks, without warps, and without rejects.

But unlike rough seas, the agitation in this quench bath is far from wild and uncharted. It is scientifically measured turbulence of a *specific flow velocity,* tested and known to bring out the best of the desired qualities of the product in work. Heat extraction is always uniform. Results are predictable and *fixed.*

Tailored turbulence such as this is made possible only by the careful correlation of the quenchant flow rate with the as-quenched properties of the product.

Our application engineers can help you draw such a correlation in *your* quenching operations. They'll specify the appropriate mixers and cooperate in the design of the tank.

For information, write us or call your LIGHTNIN Mixer representative listed in Thomas' Register and in the yellow pages of your telephone directory.

Lightnin® Mixers

MIXCO fluid mixing specialists

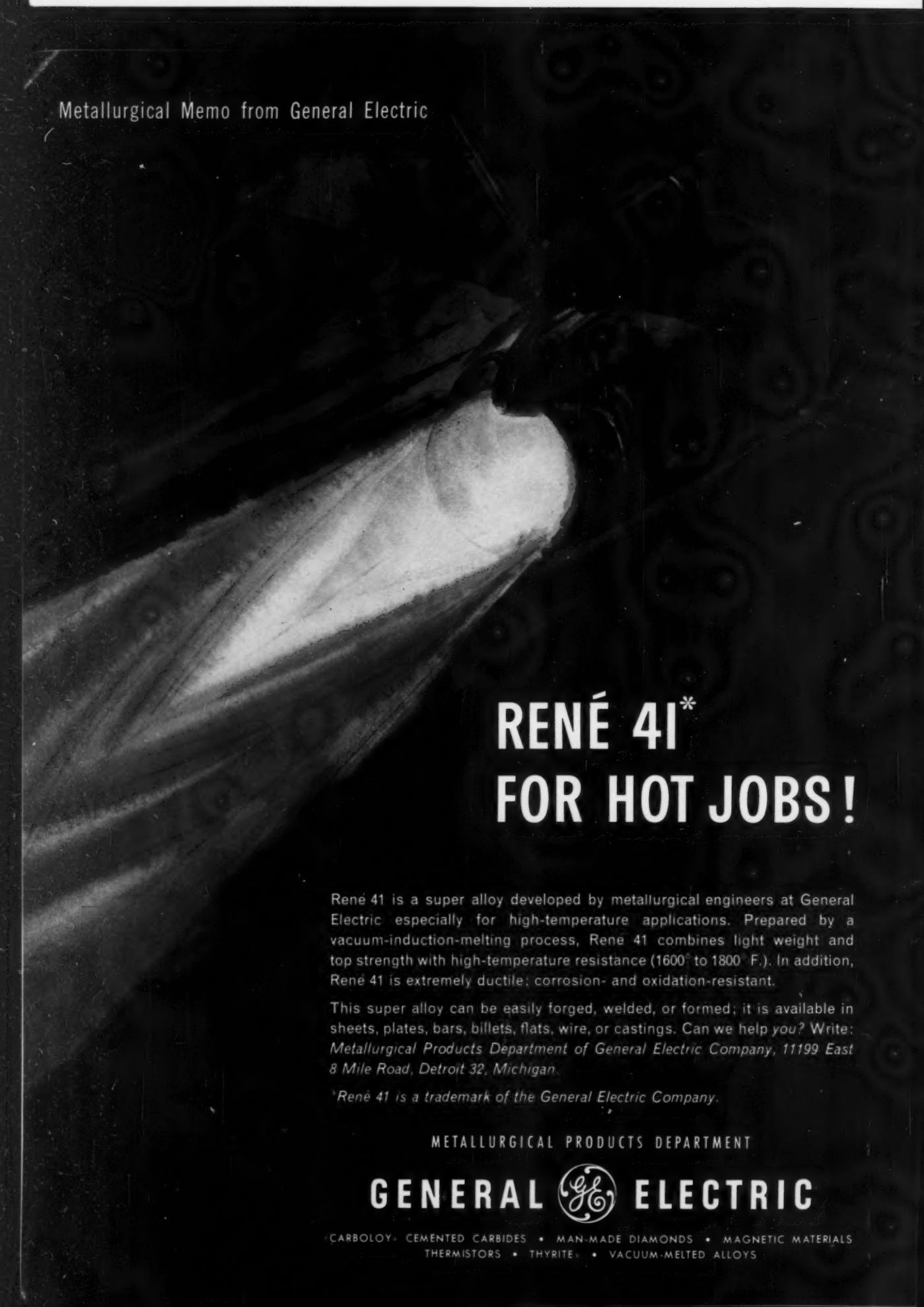
MIXING EQUIPMENT CO., Inc., 171-h Mt. Read Blvd., Rochester 3, N.Y.

In Canada: Greey Mixing Equipment Ltd., 100 Miranda Avenue, Toronto 19, Ont.

In Europe: Lightnin Mixers Ltd., Poynton, Cheshire, England

Circle 820 on Page 48-S

Metallurgical Memo from General Electric



RENÉ 41* FOR HOT JOBS!

Rene 41 is a super alloy developed by metallurgical engineers at General Electric especially for high-temperature applications. Prepared by a vacuum-induction-melting process, Rene 41 combines light weight and top strength with high-temperature resistance (1600° to 1800° F.). In addition, Rene 41 is extremely ductile; corrosion- and oxidation-resistant.

This super alloy can be easily forged, welded, or formed; it is available in sheets, plates, bars, billets, flats, wire, or castings. Can we help *you?* Write: *Metallurgical Products Department of General Electric Company, 11199 East 8 Mile Road, Detroit 32, Michigan.*

Rene 41 is a trademark of the General Electric Company.

METALLURGICAL PRODUCTS DEPARTMENT

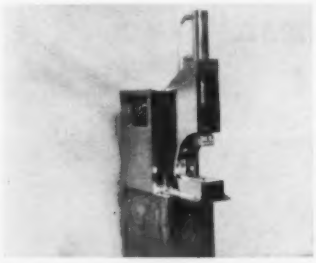
GENERAL ELECTRIC

CARBOLOY • CEMENTED CARBIDES • MAN-MADE DIAMONDS • MAGNETIC MATERIALS
THERMISTORS • THYRITE • VACUUM-MELTED ALLOYS

statistical quality control of production welding, or setting up weld schedules. The units are available in two models having a testing range of 0 to 50 lb. or 0 to 100 lb. Both models feature a load indicator, which holds maximum specimen pull until reset, and an anti-backlash mechanism which prevents surge readings at the breaking point. *Hughes Aircraft Co.*
For further information circle No. 553 on literature request card, p. 48B

Bench Model "Spike" Welders

The advantages of spike welding for joining dissimilar metals such as titanium, tantalum, tungsten, zirconium, Kovar, and other hard-to-weld metals are: low heat effect in weld



zone; reduced shunt effect; lower weld pressures; and a columnar current pattern. Four models in the "S-Series" line have a weld-pressure range down to 2 lb. for delicate precision work, and a work range extending from 0.001 in. diameter wire up to husky parts for transistors. *National Electric Welding Machine Co.*
For further information circle No. 554 on literature request card, p. 48B

Cutting Torch

Harris Calorific Co. is introducing a medium-pressure cutting attachment, "Model 73," which can be used with any of their welding torches to cut up to 6 in. of steel. The unit employs the head-mix principle and is virtually impossible to backfire. Five cutting tips (0 through 4) may be used and special tips are available for jobs such as thin-plate cutting, gouging, or rivet cutting and washing.
For further information circle No. 555 on literature request card, p. 48B

Metal-Removal Torch

Designed primarily for pad washing in steel and alloy foundries, the "Model V" torch is also useful for sprue removal and other heavy-duty cutting, gouging and beveling operations. Features include a spring-steel wire guard to prevent accidental arcing; open-head construction for good visibility; and light weight for easy handling. Available in three sizes – for ½, ⅝ and ¾-in. electrodes – this carbon arc-air torch requires current varying from 400 to 1600 amp., depending on type of work and size of electrode. *Arcair Co.*
For further information circle No. 556

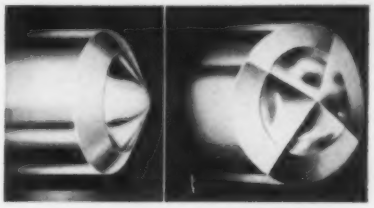
Testing

Portable Magnetic Tester

For nondestructive testing applications where portability and high power are desired, a light weight magnetic particle tester from *Picker X-Ray Corp.* can be employed. The "Portable Ferroscope" produces 1000 amp. of a-c. or half-wave d-c. to detect surface and subsurface flaws in marine, aircraft, bridge or other heavy construction. For maximum flexibility, it operates with coils or prods (either mounted as a pair for one-hand operation, or used separately).
For further information circle No. 557

High-Temperature Hardness Indentor

The basic component in this high-temperature (3000° F.) indentor is a sapphire mounted in a molybdenum shank. It is manufactured in two shapes – sphero-conical and pyramidal (Vickers 136° angle). Shanks can be mounted in all standard testing machines or made to suit special requirements. *F. F. Gilmore & Co.*



For further information circle No. 558 on literature request card, p. 48B

Mr. SHOTT and Mr. GRITT

"One thing that may have been giving you trouble . . . you've got the wrong sock on your driver!"

For a better finish start with AMSTEEL SHOT AND GRIT
GENUINE ELECTRIC FURNACE STEEL ABRASIVES

ALLOY METAL ABRASIVE COMPANY
ORIGINATORS OF CAST STEEL SHOT
121 South Division Street, Ann Arbor, Michigan Phone: NOrmandy 3-8529
Circle 822 on Page 48-B

"We had 18-20 hours downtime every time we changed heats. With strip, we just hook on from heat to heat. No downtime."

"With strip we use smaller blanks to produce the same part."

"By using strip we save downtime, die repairs."

"Rejects have dropped from about 8% to less than 1%."

"We found we couldn't afford the low cost of sheet."

Read why Target Stamped Products, Inc., Kinsman, Ohio, switched from strip to sheet—and then back to strip. Comments are Harvey Haynman's, Target's president:

"We thought we'd give sheet a try back in 1958. The low cost looked too good to pass up. Today, you'd have a hard time finding a piece of cold rolled sheet around the shop.

"We were absorbing 18-20 hours of downtime every time we changed heats. With strip, we just hook on from heat to heat. The characteristics are the same from heat to heat and coil to coil. We don't waste time adjusting our dies.

"Strip saves us metal. We can use smaller blanks to produce the same part. I'd say we save from 1/16" to 3/32" of metal per part. That's a lot of steel when you're turning out 25-30 million parts a year.

"We don't have gauge problems now. The strip we buy is always rolled within our working tolerance. We work to a plus or minus .0025 inches.

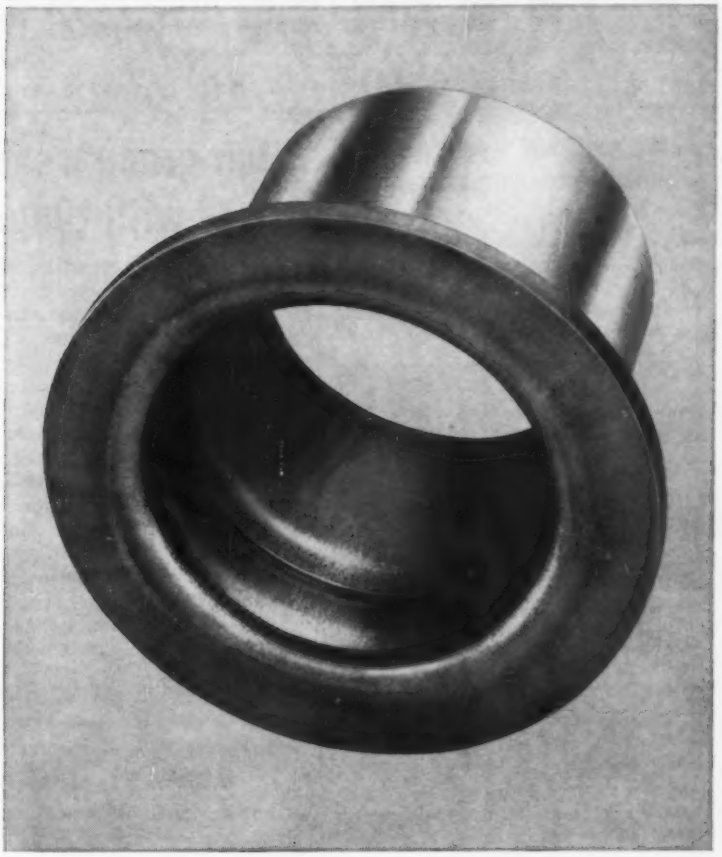
"So far, strip hasn't given us lamination troubles. It doesn't take much lamination to give you big trouble in a deep drawing operation. When the metal separates, part may stick to the punch while part stays in the cavity. As another blank transfers to the same station, there's a double smash and the die is ruined. That hasn't happened with strip. Saves a lot of downtime and die repair.

"Strip takes a deep draw without thinning out on you. Its uniform temper pays off when you're turning out Silent Blocks where both the ID and OD have to be right or the part's a reject.

"All in all our rejects have dropped from about 8% to less than 1% since we switched back to strip.

This mark tells you a product is made of modern, dependable Steel.

Outer metal bushing of a Silent Block. Target Stamped Products turns out millions of these each year for the auto industry. Silent Blocks are used in the suspension systems of all American cars—about eight to a car. To produce the piece, Target must work to a plus or minus .0025" tolerance or the Silent Block won't work. When Target switched back to strip, their rejects dropped from about 8% to less than 1%.



"You can have all the automation in the world, but if you're using the wrong steel, it just nickels and dimes you to death. With strip our machines keep working; we need less supervision, less tool repair. Our trim is small and our percentage of rejects is the smallest we've ever known. We found out we couldn't afford the low cost of sheet. That's why we're back with strip."

The switch is back to strip

Cold rolled sheet steel can be your best buy on a cost per pound basis. Certainly its quality has risen sharply since the war. But, pound cost is only part of the story. If you really need steel tailored to your specific production requirements, cold rolled strip is the answer.

Strip is not sold on an as-rolled basis. What you buy is a specific chemistry, temper, dimension, edge and finish to precisely meet your fabricating and end-use requirements.

American Steel and Wire has over 12,000 mill practices in available strip specifications. Many of your processing steps may actually be eliminated by using cold rolled strip.

Take a hard look at your production line and let our salesmen look with you. Check your rejects, your downtime, your scrap rate. Perhaps you can improve the quality of your product and cut production costs at the same time, with *tailored-to-the-job* cold rolled strip from American Steel and Wire. American Steel and Wire Division, Rockefeller Building, Cleveland 13, Ohio. USS and American are registered trademarks

American Steel and Wire Division of United States Steel

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors
Tennessee Coal and Iron Division, Fairfield, Ala., Southern Distributors
United States Steel Export Company, New York, Distributors Abroad

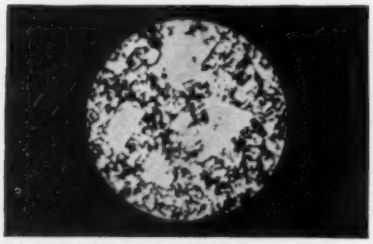
Circle 823 on Page 48-B

Linde Coatings & materials News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Abrasives, 99.98% pure alumina, simplify polishing of metals

Once it was a complex art to put precision finishes on metals. Polishing, sharpening, honing involved many abrasives and techniques. Now, with LINDE *alumina* abrasives, metallographic polishing is routine.



Magnified 1500 X—a sample of tungsten carbide with 6% cobalt binder polished by modified procedure for hard materials. (Murakami's etch).

In three grades LINDE 0.3 A (alpha alumina), LINDE 0.05 B (gamma alumina), and LINDE 1.0 C (alpha alumina)—these low-cost, fast-cutting white powders can be used with many materials. LINDE 1.0 C removes material rapidly; LINDE 0.3 A cuts quickly, yet leaves a clear, unsmeared finish; LINDE 0.05 B cuts slower but produces a finer finish. Uniformity of the particle size eliminates levigation in finishing.

Powders can be used dry, or mixed with water or other vehicles to make a thin slurry or heavy paste, or compounded with waxes in convenient stick form. Both are highly resistant to common acids. Check, send the coupon.

Now—high workability for tungsten in crystal form

Ingots of LINDE crystal tungsten can be worked into intricate shapes for electronic, other applications. It can be done at room temperature, using standard machine tools. Metal has no porosity, relatively low impurity, is less brittle than PM tungsten. Crystal tungsten also has unusual ductility, has been drawn into wire as fine as 1 mil for greater yield of finished product from starting ingot. Check, send the coupon for details.

High-grade wear from lower-grade metals —with tungsten carbide coatings

Bearings on the torque meter shaft of a turbo-prop aircraft engine gave only 50 hours operating life, even though the bearings were heat-treated. The short life was caused by severe fretting corrosion. Then the bearing surfaces were given a tungsten carbide coating with LINDE's Flame-Plating process. Service life is now greater than 1500 hours.

A critical tolerance had to be maintained between a ball piston and the piston wall in a hydraulic pump. Carbide inserts mating with steel balls proved unsatisfactory due to differential expansion at operating temperature. Carbide balls added considerable weight. The problem was solved with Flame-Plated steel bushings which had the correct expansion rate and a wear resistance equal to solid carbide—at considerably less weight.

Aluminum toughened

In another situation, aluminum rocker arms were being used in an aircraft heater mechanism to keep weight under overall requirements. But, because of severe sliding abrasion, the relatively soft metal lasted only about 100 hours. When the wearing surface was given a precision coating of tungsten carbide, service life jumped to more than 1000 hours. And the desirable light weight of aluminum was not lost.

These are typical examples of how LINDE's custom-coating service can be used to upgrade many ordinary metal parts by coating their wearing surfaces with tungsten carbide, aluminum oxide, tungsten, molybdenum, other oxides and materials. The thin coatings multiply wear performance many times over—but at the lower costs and with the retention of the other desirable properties associated with the base metals.

If you need technical information on particular problems with wear caused by abrasion, corrosion, erosion—even under conditions of severely high temperature, high load, or absence of lubricant or cooling—LINDE can help you. Check and send the coupon below.

PHYSICAL DATA—FLAME-PLATED COATINGS

COATING DESIGNATION	LW-1	LW-1N	LW-5	LC-1A	LA-2
Approx. Composition by weight	Tungsten Carbide + 6% to 8% Co	Tungsten Carbide + 13% to 16% Co	25% WC + 7% Ni + mixed W-Cr Carbides	85% Cr_3C_2 + 15% Ni-Cr	99% + Al_2O_3 (gamma)
Hardness Vicker's (VPN_{300})	1200 to 1450	1050 to 1150 VPN 70 to 71 R.	1000 to 1200 VPN	850 VPN	1000 to 1200 VPN
Maximum temp. in oxidizing atmosphere	1000°F.	1000°F.	1400°F.	1800°F.	1200°F. to 1800°F.
Coefficient of thermal expansion	4.0 x 10 ⁻⁶/°F. Avg. 70 to 1000°F.	4.7 x 10 ⁻⁶/°F. Avg. 70 to 1000°F.	4.6 x 10 ⁻⁶/°F. Avg. 70 to 1400°F.	6.4 x 10 ⁻⁶/°F. Avg. 70 to 1800°F.	3.9 x 10 ⁻⁶/°F. Avg. 70 to 1832°F.
Modulus of Rupture	67,000 psi	80,000 to 106,000 psi	40,000 psi	75,000 psi	22,000 psi
Modulus of Elasticity	44 x 10⁶ psi	42 to 40 x 10⁶ psi	17 x 10⁶ psi	22 x 10⁶ psi	16 x 10⁶ psi
Porosity	0.5%	0.5 to 1.0%	0.5%	0.5%	1.0%
Specific Gravity	14.2	13.2	10.1	6.54	3.45
Specific Heat	0.048	0.056	0.070	0.127	0.196
Thermal Conductivity	5.3 at 500°F.	5.3 at 500°F.	3.8 at 500°F.	4.3 at 500°F.	0.86 at 500°F.
Main features	Extreme wear resistance	Excellent wear resistance + increased resist. to mechanical and thermal shock.	Excellent wear resist. to higher temps. Improved corrosion resist.	Good wear resist. at high temp. or in corrosive media. Resists flame impingement.	Excellent resist. to wear, chem. attack and high temperature deterioration.

CHECK—CLIP COUPON—ATTACH TO BUSINESS LETTERHEAD

Linde Company, Dept. MP-08
270 Park Avenue
New York 17, N.Y.

Please send details on the items checked:

- ☐ LINDE Flame-Plated Coatings
- ☐ LINDE Alumina Abrasives
- ☐ LINDE Arc Crystal Tungsten

UNION CARBIDE

LINDE COMPANY

"Linde" and "Union Carbide" are registered trademarks of Union Carbide Corporation

New
Allegheny Stainless
Bar Program
Means . . .

FAST DELIVERY

BETTER MACHINABILITY

UNIFORM IMPROVED PROPERTIES

TOP QUALITY PROCESSING

FAST DELIVERY—

5,000,000 lbs. of finished bars
8,000,000 lbs. of semi-finished stocks
to back-up distributor inventory

Allegheny Ludlum now stocks at the mill depots, Rounds, Hexagons, Squares, Flats and Forging Billets in the ten most popular grades that account for over 85 percent of all stainless bars made. This huge stock of over 2,500 tons backs up the large inventories carried by the authorized Allegheny Ludlum Distributors.

In addition to the finished stock, over 4,000 tons of quality checked rerolling billets and ingots in 30 grades are in inventory to cut delivery time and to insure predictability.

Each month, A-L publishes a Bar, Wire, and Forging Billet Stock List which lists the grades, sizes, and actual pounds of each in stock at the first of that month. It's available to you through the Steel Service Centers authorized to sell A-L Stainless Bars. For the names of the distributors in your area, just call the A-L District Office.

BETTER MACHINABILITY—

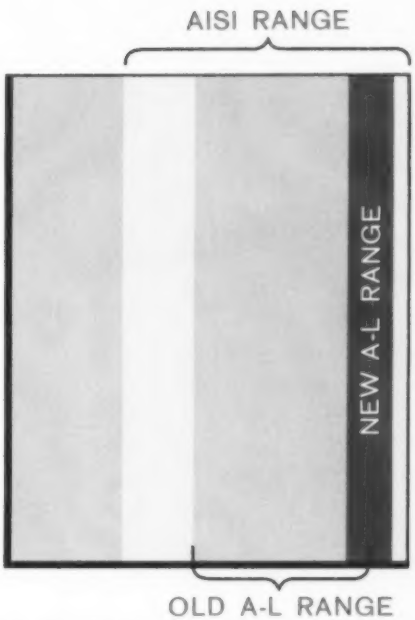
Research, Constant Testing and Controlled Processing Result in Greatly Improved Machinability and Uniformity . . . from Lot to Lot

Several years ago, A-L took a hard look at its own stainless steel bars. While quality was good, it could be made better and more uniform, particularly in the area of machinability.

One of the finest metalcutting laboratories in the country was retained to make independent, exhaustive comparative tests on A-L stainless bars and competitive bars. Ratings were based on tool life, determined by turning and drilling tests. A-L's Research Center, probably the largest in the stainless business, correlated these results with metallurgical factors such as composition, microstructural and mechanical properties.

From Research to the melt shops went instructions to revise and narrow the limits of composition. This, combined with processing changes, yields general purpose (stocked) grades with predictable, better machinability.

RESULT: Testing general purpose machining grades as made three years ago with the same grades made today shows better than a 50 percent increase.



ANALYSIS LIMITS

Allegheny Stainless composition limits, already much tighter than AISI Specifications, have been narrowed even further to improve the composition-sensitive machining properties of all A-L Stainless Grades.

MACHINING TESTS

Exhaustive turning and drilling tests on stainless bars of all types pin-pointed the composition and processing variables that most affected machining properties, and made possible the adjustment of these variables for improved machinability and predictability of response from heat to heat. A continuing program of these machining trials serves as an additional safeguard to the quality and unmatched dependability of an A-L Stainless Bar.

TOP QUALITY PROCESSING—

Special Care and Special Equipment Mean Better Bars at Your Machines

What's been your big trouble with cold finished stainless steel bars . . . nicks and gouges, off-size, burred ends, grinding marks, damaged shipments? Glance over the panels at the right, and see how these common faults are eliminated from Allegheny Ludlum cold finished stainless bars.

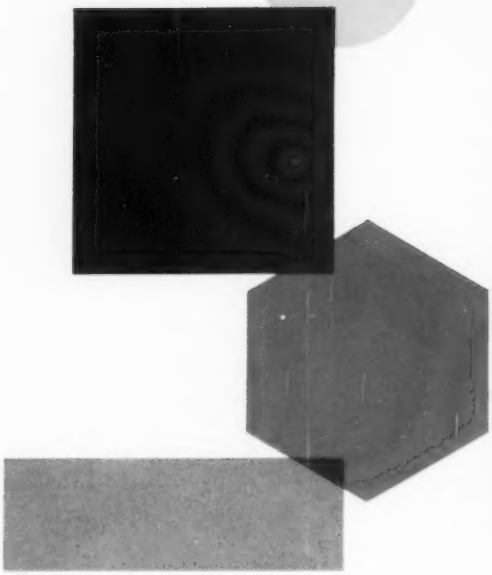
These are precautions that make a difference between an A-L quality bar and all the others . . . quality you can see, and feel, and measure. Quality that shows up in bar automatics, in all your fabricating.

And this quality is no accident. A few years ago, Allegheny Ludlum investigated stainless bars from the customer's viewpoint. A-L teams held field interviews, toured customer's plants, watched stainless bars undergoing every conceivable fabricating operation. A good part of the trouble was in mill finishing. And A-L revamped their entire finishing operation to suit.

Special equipment is installed, and every operation becomes a matter of painstaking care. Rubber padding covers every work table and inspection table, lines every transfer buggy . . . chain and cable slings are eliminated, and soft rope substituted . . . cardboard collars are fitted to bars in process, to prevent rubbing and scratching.

Quality Audit Teams continually audit and maintain quality control standards by making pinpoint quality checks through every phase of production . . . right onto the shipping dock.

Many of these practices have been widely imitated in the industry. Some are still A-L exclusives. But, this is how quality is made . . . stainless steel bar quality . . . by the world's leading stainless steel producer.



HEAT NUMBERS ON EVERY BAR

Heat numbers stamped permanently on one end of the bar won't wear off, can't get separated. Square, clean-cut and deburred ends make ass in bar automatics easier and make chucking simpler.

CONSISTENT SIZE AND STRAIGHTNESS TOLERANCES

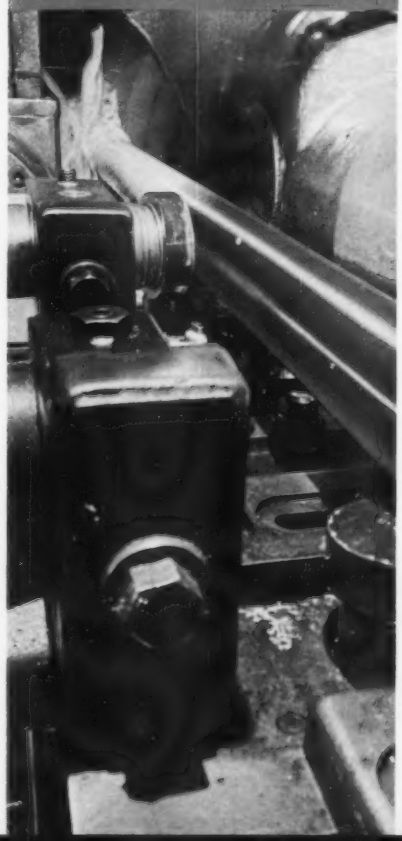
A-L's famous quality control and inspection procedures mean greater uniformity . . . minimizes special handling in your plant.

NICK-FREE, SCRATCH-FREE BARS

Nothing harder than cardboard, ropes or rubber ever touches finished A-L bars. Cardboard collars eliminate sliding, metal-to-metal contact . . . chain or cable are never used.

CAREFUL FINISHING PAYOFF

Multiple passes through centerless grinders result in smooth finish—no spiral grind marks —no chatter marks.



PROTECTED SHIPMENTS

All bars are protected with cardboard collars and then the bundle is completely wrapped with triple-thickness waterproof paper to protect the superior finish during shipment. Reduces damage in transit.

SMOOTHEST FINISH AVAILABLE

Consistent metal quality and careful finishing result in a surface vastly superior to the industry-accepted average standard.

And if You Want Something Special A-L is a Complete Bar Source

HIGH TEMPERATURE STEELS & ALLOYS

A-L stocks certain finished bars in the most commonly used high temperature steels and alloys plus a large stock of approved billets in these same grades. Needs for bars of A-286, 19-9DL, AM-355, Waspaloy, AL 901, R 41, S-816, M-252, etc., are usually quickly satisfied from this finished and semi-finished stock of Allegheny Ludlum.

FORGING BARS & BILLETS

Also in stock is a full range of forging-quality bars and forging billets from 4 to 30 inches Round Cornered Squares in a wide range of grades, all meeting appropriate specifications.

SPECIAL ANALYSIS AND PROCESSING

For special requirements, A-L is able to tailor-make properties to fit the end use. From knowledge gained in the machining research program, chemistry and processing can be varied to increase a specific property for a particular application. Improvements in such things as hot workability, cold workability, hardenability, finish after machining, improved machinability in non-free machining steels, mechanical properties, corrosion resistance, are examples.

It's something you should discuss with your A-L sales representative.

MACHINING AND HEAT TREATMENT DATA

A-L mill and research specialists are available, through the A-L sales representatives, for help and counsel on problems involving Allegheny Stainless Bars. Qualified machining engineers are at your service. These men devote their full time to provide the best service and assistance available anywhere.

NEW BAR BOOKLET

On the printing press now is A-L's new booklet, jam-packed with helpful information on using, heat treating and machining Stainless Bars. For a copy of this technical, data-filled booklet, check the A-L authorized distributor in your area, or the A-L Sales Office nearest you, or write: ***Allegheny Ludlum Steel Corporation, Department QIP 3, Oliver Building, Pittsburgh 22, Pa.***

ALLEGHENY LUDLUM

EVERY FORM OF STAINLESS . . . . EVERY HELP IN USING IT

3473

furnace atmosphere control?

M-S-A® LIRA® Infrared Analyzer Model 300. 10¼" wide. 8" high. 20" long.

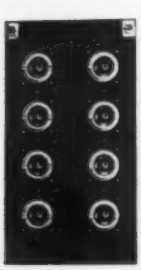
new from MSA: simplified, low-cost infrared analysis of furnace atmospheres

Here at last is a new, low-cost infrared analyzer that greatly simplifies measurement of CO, CO_2, methane and dew point.

The new M-S-A® LIRA® Model 300 is *not* complex. Fact is, it's a very easy instrument to live with. As an effective check against quality control problems in furnace atmospheres, this unit is invaluable. It really helps reduce rejects.

The LIRA 300 is compact and lightweight. Entire assembly is mounted on a single roll-out tray. And if portability is desired, a handle can be added.

More information? Please state your particular problems of atmospheric analysis and control when you write for our informative new bulletin.



For Total Combustibles: M-S-A® Combustible Gas Analyzer

For Hydrogen: M-S-A® Gas Thermatron

For Oxygen: M-S-A® Oxygen Analyzer

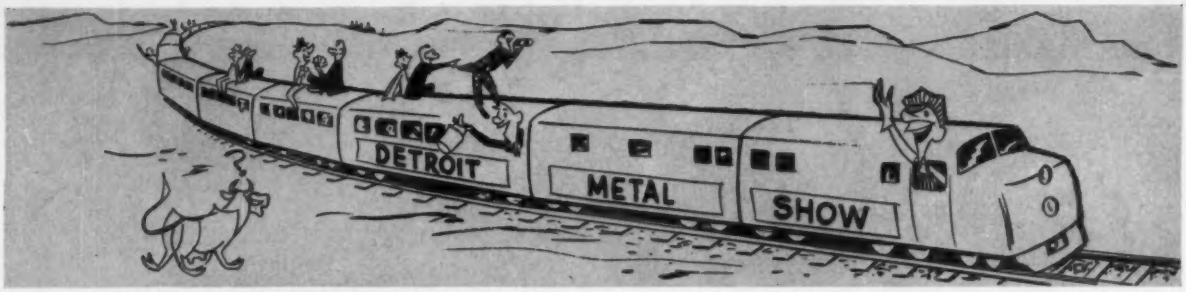
MSA

INSTRUMENT DIVISION

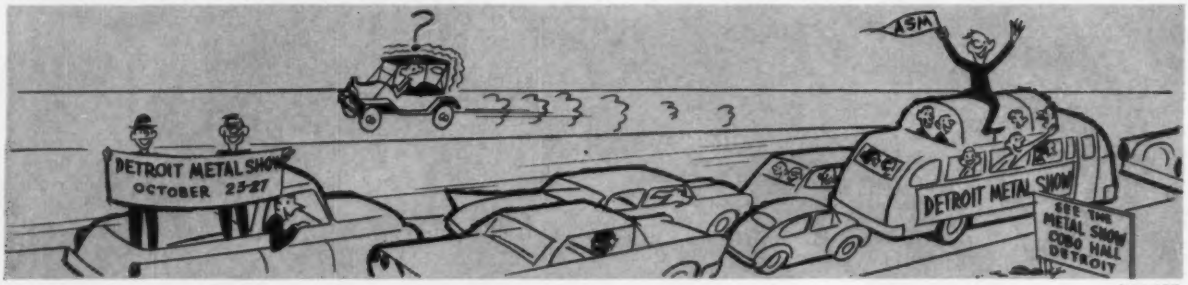
Mine Safety Appliances Company

Pittsburgh 8, Pennsylvania

Circle 826 on Page 48-B

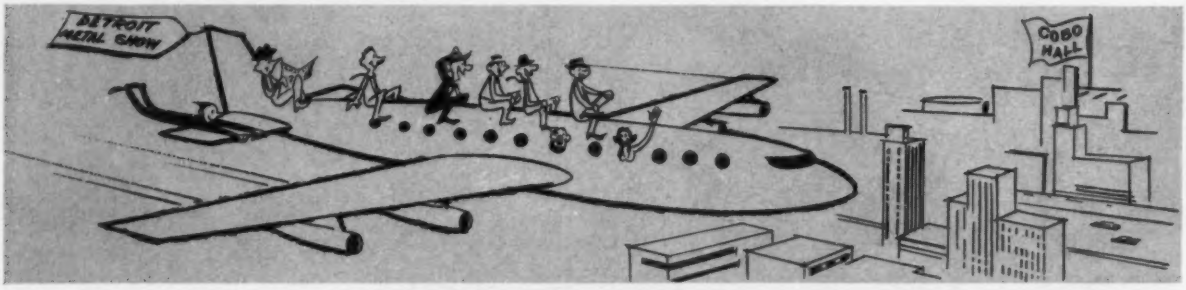


EVERYONE...



10405-ASM

(Well, almost everyone)...



is headed for the 1961 DETROIT METAL SHOW

THE WORLD'S MOST COMPREHENSIVE METALS AND PROCESSING EVENT

OCTOBER 23RD THROUGH 27TH • COBO HALL

Ideas . . . Ideas . . . Ideas . . . stimulating, thought-provoking ideas. How to improve production . . . how to cut costs . . . how to stay ahead of competition. SEE – hundreds of educational exhibits. HEAR – presentation of over 200 technical papers. EXAMINE – processing, inspection and control equipment. VISIT – the spectacular Materials Comparison Center. Yes, *everyone* . . . especially the IDEA man for his company . . . is headed for the 1961 Detroit Metal Show. He wants to *KNOW* more . . . DO YOU?

PLAN NOW TO ATTEND THIS GREAT SHOW!

ORGANIZE A COMPANY GROUP FOR TRAVEL AND ACCOMMODATION ECONOMY!

USE THIS CONVENIENT ADVANCE SHOW REGISTRATION FORM! You will receive your ASM INFORMA-Badge, your credit card guest permit to the show.

Advance Registration Manager, ASM Headquarters, Metals Park, Ohio
Gentlemen: Please register myself (and the names of my associates listed below) for the forthcoming METAL SHOW at Cobo Hall in Detroit.

Name	Title	Indicate Affiliated Organization*	Registration Fee for ASM Sessions and Exposition: $2.00. (Except as noted below)

(Enclose check or money order) TOTAL

Company _____

Address _____

City _____ Zone _____ State _____

☐ ASM Members: NO REGISTRATION FEE for ASM Sessions and Exposition.
☐ AIME Members: $5.00 Registration fee includes AIME sessions, ASM sessions and Exposition;
☐ non-members: $10.00 AIME sessions, ASM sessions and Exposition.
☐ SNT Members: $5.00 Registration fee includes SNT sessions, ASM sessions and Exposition;
☐ non-members $7.00 SNT sessions, ASM sessions and Exposition.

Circle 827 on Page 48-B

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

Steel *for Strength . . . Economy . . . Versatility*

Flame-Hardening Alloy Steels

The process known as flame-hardening involves the direct application of flame to the surface of steel, heating it above the transformation range, then hardening it by quenching. The primary purpose of this process is to achieve surface-hardness without affecting core properties. Jets of flame are played directly on the steel, and hardness penetration can be made to vary considerably. In alloy steels this depth will range usually from 0.03 to 0.12 in., the actual figure depending upon the method of heating and quenching used.

Unlike carburizing, flame-hardening does not involve the absorption of extraneous elements by the steel. There is no alteration of the chemical composition. To put it simply, the steel must have its own self-hardening characteristics; it cannot be dependent upon carbonaceous salt baths, gases, and other media.

Flame-hardening is not a substitute for the conventional furnace method. Each has its uses. The particular virtue of flame-hardening is that the flames can be directed to localized areas. The furnace, on the other hand, is generally more economical and feasible when parts produced in large quantities must be hardened all over.

Any type of hardenable steel, alloy or carbon, can be flame-hardened, and there will usually be no scale or pitting. The alloy content is the governing factor when determining the quench. In some cases a rapid quench is required; in others, it can be as slow as air-cooling. Tempering presents no problems, for flame-hardened steel can be tempered as if hardened to the same degree by other methods.

A list of typical flame-hardened parts includes such familiar items as gear and sprocket teeth, and certain types of cams and rollers, and shoe treads. A complete list would include many other parts that often require a localized hardening treatment, especially for wear-resistance.

When you need information about flame-hardening methods, please feel free to consult with our technical staff. Bethlehem metallurgists will work with you, at no obligation, and you can depend on their suggestions. You can rely on Bethlehem, too, as a source of alloy steels . . . for Bethlehem makes the complete range of AISI standard grades, as well as special-analysis steels, and all carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

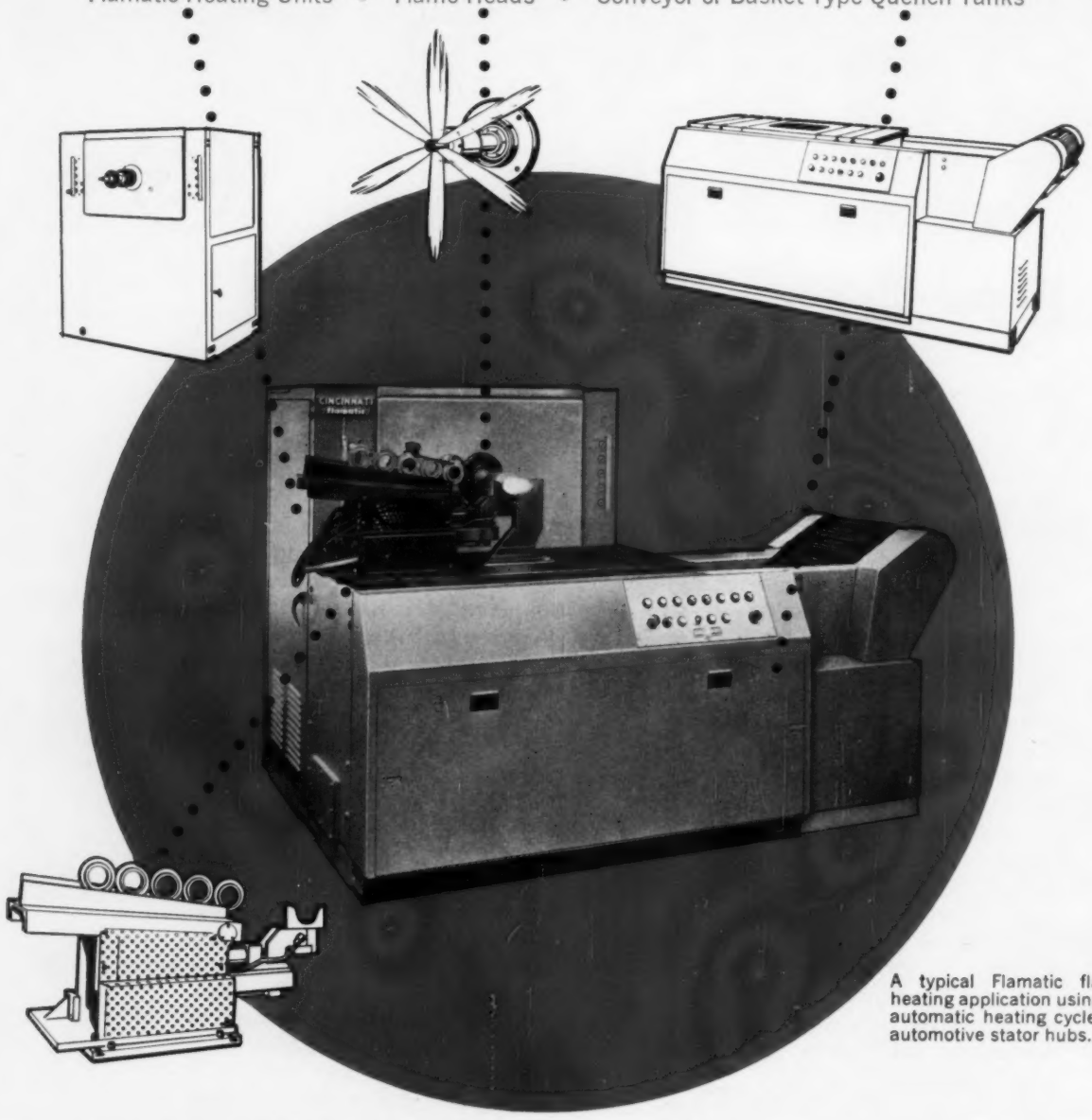
BETHLEHEM STEEL COMPANY, BETHLEHEM, PA. *Export Sales:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 828 on page 48-B

Work Handling Devices • Natural Gas Boosting Equipment • Electronic Temperature Controls
Flamatic Heating Units • Flame Heads • Conveyor or Basket Type Quench Tanks



A typical Flamatic flame heating application using an automatic heating cycle for automotive stator hubs.

CINCINNATI® Advanced Heat Engineering Cuts Flame Heating Costs

Flamatic® building block design lets you purchase standard units that can be assembled into a flame heating machine custom tailored to your operation. You buy only the components necessary to do the job—nothing more—and materially reduce your initial investment costs.

When requirements change, a variety of pre-engineered flame heating units, flame heads, work handling fixtures, and quench tanks are available to convert the Flamatic to meet new job specifications at the lowest possible cost.

For detailed information about the advantages of new Cincinnati Flamatic building block design, write us, or call a Meta-Dynamics application engineer.

Circle 829 on Page 48-B

META-DYNAMICS DIVISION

CINCINNATI

THE CINCINNATI MILLING MACHINE CO.

Cincinnati 9, Ohio

NEW LITERATURE

Steel

561. Strip Mill Products

80-p. reference book spells out the basic information needed to intelligently understand and order strip steel, spring steel, shim steel, electro-galavanized strip steel and flat wire products. *Mill Strip Products Co.*

562. Steel Tubing

Order the exact tube O.D.'s you need from 2.25 to 50 in., with wall thicknesses from ¼ to 8 in. Details on "Ceram-Spun" process available from *Acipco Steel Products Div.*

563. PH Stainless Steels

These steels offer adequate strength and better corrosion resistance than the hardenable grades of chromium stainless. Details from *Republic Steel Corp.*

564. PH Stainless

Armco Steel Corp. will send data on 17-4 PH stainless steel. Strongr than Type 416; as corrosion resistant as 18-8 stainless.

565. Alloy Steel Booklet

"Quick Facts About Alloy Steels" published by *Bethlehem Steel Co.* Elementary information on steel heat treatment, properties, and microstructures.

566. Property Charts

Wallace Barnes Steel Div. has published "Physical Property Charts" on properties and formability of tempered steel.

567. Cryogenic Service

27-p. booklet "Steels for the Containment of Liquefied Gas" has been issued by *International Nickel Co.*

Nonferrous

569. Sintered Titanium

4-p. Bulletin No. 100 "Designing With Sintered Titanium" pinpoints cost-saving potentials of sintered titanium in modern design. *Clevite Corp.*

570. Literature Surveys

The *Cobalt Information Center* has literature surveys on cobalt-nickel coatings and cobalt-nickel alloy properties.

571. Selection Chart

Seymour Manufacturing Co. is offering an "Alloy Selection Chart" for nickel silver, phosphor bronze, brass, copper, and stainless steel.

572 Ti-8Al-1Mo-1V Alloy

12-p. data memorandum outlines forging and heat treat procedures for the alloy and includes discussion of creep stability and fatigue properties. *Titanium Metals Corp. of America.*

573. Impact Extrusions

Alcoa has published a 34-page brochure on impact extrusions entitled "Metal in Motion" which details applications and savings possible.

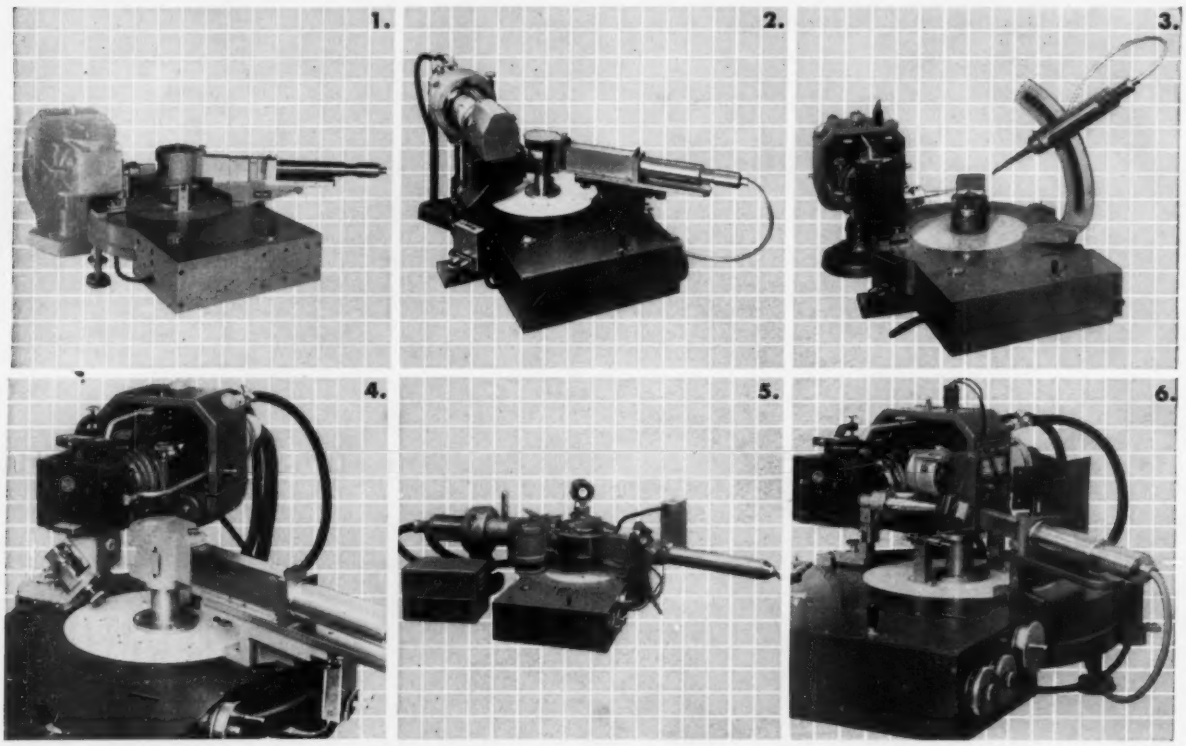
560. Steel Design and Engineering

Four papers which discuss advances in strength levels and product forms, as well as design applications of constructional steels, have been published in

a 59-p. brochure, "New Concepts in Steel Design and Engineering". Descriptions of actual designs show how the modern "family" of constructional steels are employed in structures and equipment to achieve higher strength, lighter weight and lower costs. *U.S. Steel Corp.*

Circle appropriate number on Reply Card, p. 48-B

X-RAY DIFFRACTION AND SPECTROSCOPY



1. Counter Tube Diffractometry. 2. Spectroscopy. 3. Single Crystal Studies. 4. Spectroscopy of Small Areas. 5. Vacuum Spectroscopy of Light and Heavy Elements. 6. Studies of Orientation.

VERSATILITY!

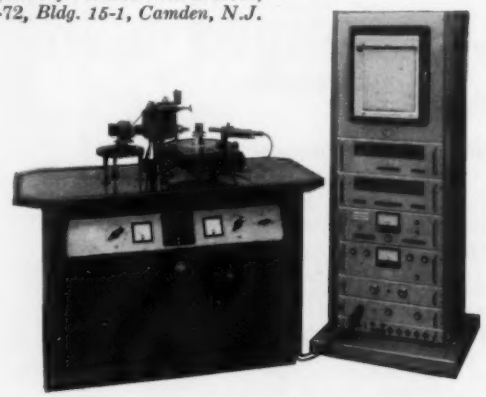
RCA's horizontal goniometer performs 6 functions

Unusual versatility is an important distinguishing characteristic of RCA's X-Ray Diffraction and Spectroscopy Equipment. This versatility is graphically demonstrated by the horizontal goniometer which can perform six different functions merely by adding accessories, as illustrated above.

RCA X-Ray Diffraction and Spectroscopy Equipment offers many other outstanding features which make it one of today's most specified lines. For example, the DC regulated and filtered power supply; the option of mounting two tube stands on the Crystalloflex IV; a kit which permits conversion from diffraction to spectroscopy in minutes; and the new vacuum spectrometer for analysis of light and heavy elements. For those engaged in film studies of all kinds, the RCA Table Model Crystalloflex II can be bought, complete with cameras, for as little as $4000.

A NEW LEASING PLAN now makes it possible to obtain all RCA scientific instruments, including the Electron Microscope, with no down payment, low monthly terms, and a favorable option to buy.

For complete information write to RCA, Dept. Y-72, Bldg. 15-1, Camden, N.J.



Crystalloflex IV and Electronic Circuit Panel with Diffractometer and Guinier Camera mounted on the generator.

The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

Circle 830 on Page 48-E

574. Stock Catalog

290 pages of stock information on nonferrous and stainless steel mill products. Latest government and society specifications included. Data from *Meier Brass & Aluminum Co.*

575. Rare-Earth Metals

The Lunex Co. will send pamphlet describing the properties of high-purity rare-earth metals including lanthanum, yttrium and gadolinium.

576. Conductivity Rating

8-p. bulletin provides a rapid check list for electrical conductivity ratings of 56 copper alloys. *Bridgeport Brass Co.*

577. Gadolinium Metal

Data sheet from *Nuclear Corp. of America* presents physical, electrical, magnetic and mechanical property information on gadolinium.

578. Copper-Lithium Alloys

Articles on the copper-lithium system are described in annotated bibliography. Abstracts cover all published literature and are arranged in chronological order. *Foote Mineral Co.*

579. Ultra-Pure Metals

Union Carbide Metals Co. will send pamphlet discussing columbium, tantalum and vanadium ingots made by a new vacuum process — electron beam melting.

580. Beryllium Copper

Leaflet issued by *Brush Beryllium Co.* covers "Brush 190", a mill heat treated Be-Cu strip with tensile strength of 190,000 psi and improved formability.

581. Light-Metal Products

Brooks & Perkins, Inc. has released a pamphlet relating their experience in the design and production of lightweight assemblies in magnesium, aluminum, titanium, zirconium and beryllium.

582. Molybdenum Dies

Molybdenum is now available for forging into extrusion dies for steel, titanium and other high-temperature metals. Details from *Sylvania Electric Products Inc.*

583. Copper Alloy Forging

Titan Metal Mfg. Co., has prepared a 32-p. handbook which contains complete information on copper alloy forgings.

584. Rare Earths

8-p. pamphlet outlines the facts on thorium, yttrium chemicals, and other metals and alloys of the rare-earth group. *Vitro Chemical Co.*

Materials

586. High-Temperature Coatings

Insulative coatings for the protection of missile and rocket equipment are discussed in Brochure No. 500-61 from *Swedlow Inc.*

587. Alumina Ceramics

Diamonite Products Mfg. Co. has published "Standards of the Alumina Ceramic Manufacturers Association" which contains data on production, design, purchasing, and use of alumina ceramic materials.

588. For 2300° F. Service

Electro-Alloys Div. will send pamphlet on "Supertherm", as 26% Cr, 35% Ni alloy stabilized with cobalt and tungsten.

589. Advanced Materials

Carborundum's 8-p. pamphlet "Materials For Advanced Technology" is a data-packed roundup of 12 new products for applications involving resistance to abrasion, chemicals, corrosion, nuclear radiation or high temperatures.

590. Superalloy Forgings

Brochure on superalloy forgings — Waspaloy, René 41, Astroloy, Udimet 500, and M-252. *Wyman-Gordon Co.*

591. Refractory Grains

Catalog from *Norton Co.* describes a wide range of refractory materials. Physical, chemical, and electrical properties of Al_2O_3, MgO, boron carbide, fused zirconia.

592. "Powder Metallurgy"

Quarterly publication of the *Metal Powder Industries Federation* (spring-summer 1960) features case histories of electrical applications for powder metallurgy parts.

593. Alloy Castings

For heat and corrosion-resisting applications get the better high-alloy casting at the better price. Details from *The Fahralloy Co.*

594. Rene 41

René 41 is the most dependable alloy in use today in the 1200 to 1800° F. range. Bulletin No. 86 from *Cannon-Muskegon.*

595. Pyrolytic Graphite

General Electric will send details on pyrolytic graphite which exhibits high strength at temperatures up to 5000° F. and excellent thermal and electrical conductivity.

596. Refractories

Norton Co. has published information on refractories, including magnesium oxide, zirconia, silicon carbide, titanium diboride, as well as other carbides, nitrides and borides.

597. Refractory Materials

Brochure describes boron nitride for applications such as chemical equipment parts, crucibles, brazing fixtures, gaskets, seals, and other high-temperature applications. *Carborundum Co.*

Nuclear

599. Nuclear Fuels

8-p. brochure, GEA-6762B, entitled "General Electric Nuclear Fuel" reviews design experience and quality control techniques in fabricating rod-type nuclear fuel elements. *General Electric Co.*

600. Isotope Chambers

6-p. folder provides engineering data on 19 isotope chambers for gamma radiography; available from *Philips Electronic Instruments.*

Tooling

602. Cutting Lubricant

Literature available from *Baker/Gubbins Co.* tells about a sulfurized-base cutting lubricant blend, "No. 245", which offers high film strength and lubricity.

603. Tool Steel Heat Treatment

Bethlehem Steel Co. has complete details on short cycle hardening and nitriding of high-carbon, high chromium tool steels.

604. Tool Steel Guide

A "Steelector" booklet from *Allegheny Ludlum* gives complete data on line of tool steels . . . mechanical property and heat treating information included.

605. Abrasive Wheels

Leaflets describing depressed-center abrasive wheels and "green" silicon carbide tool-grinding wheels have been issued by *Simonds Abrasive Co.*

606. Tool Catalog

480-p. Tool Catalog No. 27 presents a complete display of the *Starrett Co.* line of more than 3500 items.

607. Mold Coatings

Bulletin No. 425 discusses the consistent uniformity, quality performance and versatility of mold coatings made by *Acheson Colloids Co.*

608. Automatic Forging

Pamphlet No. 110-L-1 entitled "Cecomatic Process for the Jobbing-Type Production of Drop Forgings" will be sent to you by *Chambersburg Engineering Co.*

609. Iron Powders

Alan Wood Steel Co. has a brochure on iron powders with purity and uniformity that offers new design flexibility.

610. Finishing Hard-surfaced Deposits

Technical Data Sheet No. T-2 recommends correct grinding wheels for finishing various hard-alloy deposits. *Wall Colmonoy Corp.*

Heating

612. Thermal Fatigue

Electro-Alloys Div. has published "The Mechanism of Thermal Fatigue", by H. S. Avery.

613. Fluidized Bed Heat Treating

4-p. Bulletin GED-4306 describes fluidized bed heat treating equipment for annealing, normalizing, solutioning, aging, hardening, quenching and isothermal transforming. Up to 85% reduction in heating time. *General Electric Co.*

614. Indicator-Controllers

Thermo Electric Co. has released 4-p. Bulletin No. 67 on compact self-balancing indicators and indicator-controllers.

615. MgO Thermocouple Assemblies

Availability of Catalog 2400, covering a line of standard MgO thermocouple assemblies, was announced by *Conax Corp.*

616. High-Frequency Heating

Series of bulletins (No. 1515-1520) describe line of radio-frequency heating units which convert powerline energy to high-frequency electrical energy suitable for induction heating of metals and alloys. *Lindberg Engineering Co.*

617. Enameling Ovens

4-p. Bulletin GED-4329 describes controlled convection ovens for high-quality magnet wire enameling at twice the speed previously obtained. *General Electric Co.*

618. Draw Furnace

Pamphlet No. 14 from *Sunbeam Equipment Corp.* describes advantages and features of a gas-fired or electric furnace for continuous drawing of ferrous and nonferrous metals.

619. "Heat Treat Review"

Vol. 12, No. 2 contains an article describing the installation of a car-bottom heat treating furnace. *Surface Combustion Div.*

620. Semiconductor Production

"The Way to Better Semiconductor Production", a 20-p. booklet issued by *Lindberg Engineering Co.*, illustrates equipment for the precise control of semiconductor production.

621. Thermocouple Materials

10-p. catalog details the processes used to produce "Tempak" thermocouple materials and presents specifications on metal-sheathed, ceramic-insulated wire. *Temptron, Inc.*

To request any item listed circle appropriate number on Reply Card, p. 48-B

BL-616

NO EXTRA COST

Nothing equals it in cold finished steel bars

The finish is brighter, cleaner. There are no processing contaminants to jam collet mechanisms and slow production. The superior Lusterized Finish, possible only because of Bliss & Laughlin's patented process, can often be used for finished components without machining. Only minimum preparation is required for plating.

The Lusterized Finish is standard on all Bliss & Laughlin cold drawn carbon and alloy bars. It is protected all the way to your production points by an exclusive, colorless coating that seals out abrasive dirt, protects against rust, and neutralizes the acidity from the atmosphere.

The close tolerances, which Bliss & Laughlin pioneered, careful attention to straightness, plus the superior Lusterized Finish, make Bliss & Laughlin cold finished steel bars the *outstanding quality bar for your production*. Try Lusterized bars and you'll prove it!

Available at Steel Service Centers everywhere

Leading Independent Producer of Cold Finished Steel Bars

BLISS & LAUGHLIN

GENERAL OFFICES: Harvey, Illinois MILLS: Harvey, Detroit, Cleveland, Buffalo, Mansfield, Mass., Los Angeles, Seattle

Circle 831 on Page 48-B

622. Heat Treating Costs

General Electric Co. will send you Bulletin GER-1751 telling how to prepare an economic study of your heat processing operations.

623. Ovens and Furnaces

64-p. Catalog No. 600 from *Blue M Electric Co.* covers line of electric ovens, furnaces, "Magni-Whirl" baths, environmental cabinets and related temperature-controlled equipment.

624. Salt Baths

Brochure No. 200 covers a wide range of salt bath applications, including neutral hardening, tempering, austempering-martempering, carburizing, annealing, high-speed quenching and nitriding. *A. F. Holden Co.*

625. Diffusion Furnaces

Lindberg Engineering Co. has issued 4-p. pamphlet describing gaseous and solid-diffusion furnaces for basic, research, pilot-plant studies, and production of semiconductors.

626. Thermocouple Assemblies

Catalog G100-1 summarizes data on over 100 complete thermocouple assemblies, available in a range wide enough to cover most applications in any industry. *Minneapolis-Honeywell.*

627. Quenching Hints

E. F. Houghton & Co. will send booklet, "Houghton on Quenching", which analyzes quenching problems and recommends optimum quenches.

628. Continuous Annealing

Folder illustrates equipment for continuous annealing or surface treatment lines for thin tinplate. *Aetna-Standard.*

629. Heat Treating Salts

Eliminate scaling and decarburization in heat treating without special atmospheres — through the use of "Aeroheat" salt baths. *American Cyanamid Co.*

630. Temperature Crayons

The Markal Co. will send pamphlet summarizing information on "Thermomelt" temperature indicators; accurate to within ±1%.

631. Plugs and Jacks

Specification Sheet FS 005-3 covers "Quik-Konnect" plug and jack assemblies for fast, foolproof connection of thermocouples. *Minneapolis-Honeywell*

632. High-Temperature Furnace

Brochure No. 5805 from *C. I. Hayes, Inc.* discusses furnace with maximum range of 3300° F. for sintering, ceramic metallizing, silicon depositing and diffusing, and heat treating of exotic metals.

633. Heat Processing Facilities

Find out how extensive laboratory facilities (including a vertical bright annealing furnace) at *The Electric Furnace Co.* can help your metal-processing development and research plans.

634. Atmosphere Furnaces

Harrop Precision Furnace Co. will send full details on a line of "Kanthal-Super" atmosphere furnaces with temperatures up to 3000° F.

635. Low-Temperature Treatments

Harris Mfg. Co. has information on chilling cabinets for low-temperature processing of stainless steels.

636. Disposable Thermocouples

Pamphlet on "Jet-Temp" disposable thermocouple cartridges, which give fast and accurate readings. *General Electric Co.*

637. Gantry Furnaces

12-p. catalog discusses a complete line of furnaces — standard, modified, and special designs for your particular applications. *Pacific Scientific Co.*

638. Open-Coil Process

The uniformity of anneal possible with this process yields uniform hardness and drawing quality for coiled steel sheet. *Lee Wilson Engineering Co.*

639. Program Controller

Wheelco Industrial Instruments Div. will send Catalog F-10191 describing the "Series 2000" cam-operated program controller for the metal working, ceramic, and glass industries.

640. Heat Treating Furnaces

No matter what you heat treat, there is a "Sunbeam" furnace to do the job, more efficiently and at less cost. Details from *Sunbeam Equipment Corp.*

641. Oil-Quenching System

Combined catalog and simplified selection manual discusses "B&G" self-contained quench-oil coolers. *Bell & Gossett.*

642. Continuous Furnaces

Information on continuous furnaces for carburizing, carbonitriding, skin recovery, annealing and spheroidizing operations. *Surface Combustion Div.*

643. Radiant Tubes

The Pressed Steel Co. has issued a pamphlet on "PSC" light-weight radiant tubes available in any design or dimension.

644. Bell Retort Furnaces

Catalog MP-607 recounts the advantages of bell retort furnaces for bright

Circle appropriate number on Reply Card, p. 48-B

This process of diffusing one or more elements into the surface of steels, superalloys, or refractory metals protects them from oxidation and thermal shock failures at high temperatures. The integral alloy case won't peel or flake off, and the diffusion alloy is easily formed on internal surfaces.

Base Metals	Operating Temperature	Applications
Steels	1500°F	Heater casings, radiants, Soldering irons cores
Stainless Steel	1800°F	Jet engine control rods
Superalloys	2100°F	Jet engine turbine vanes and blades
Molybdenum	3400°F	Space vehicle components, thermocouple tubes

Thousands of CHROMALLIZED jet engine parts are now in use.
After 1800 hours of service these parts are re-CHROMALLIZED for additional life when necessary.

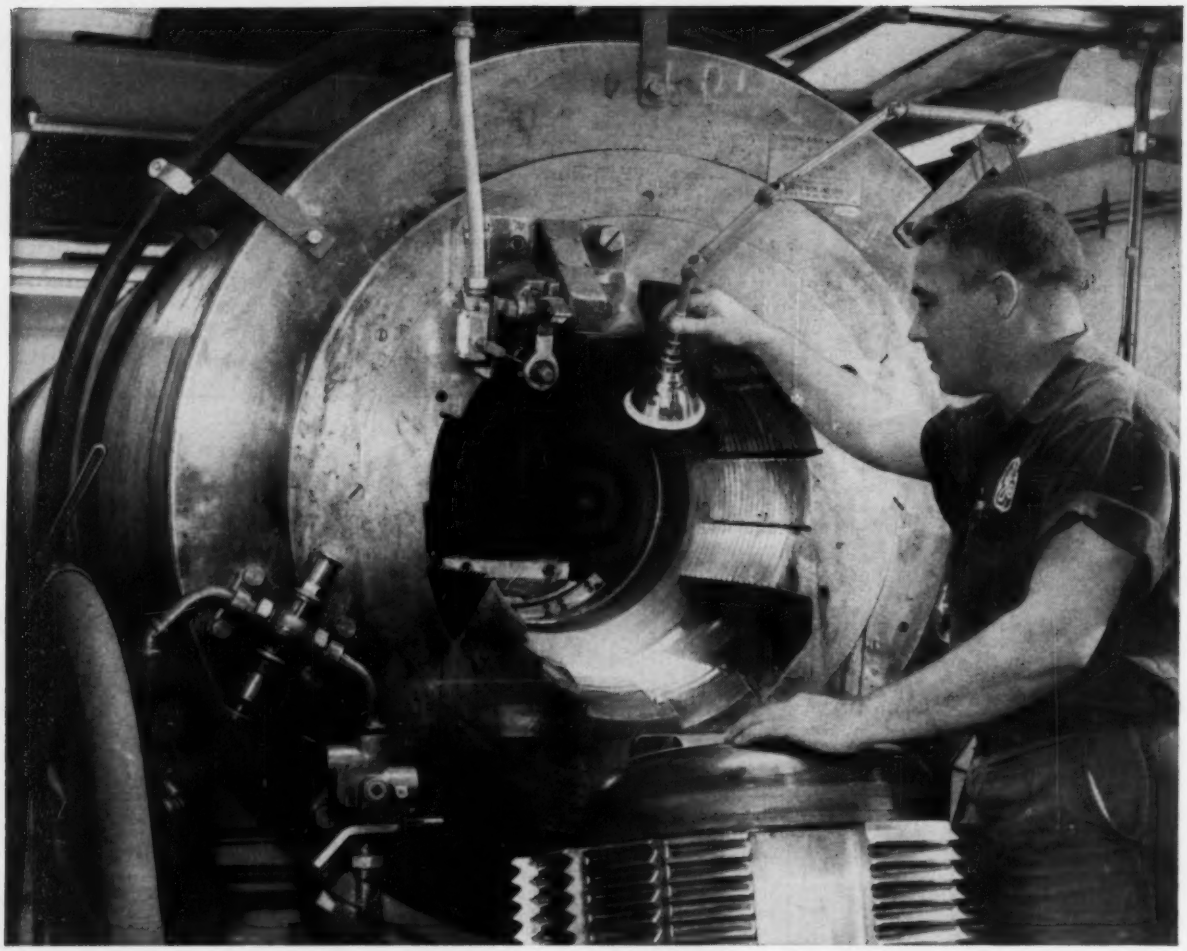
WRITE FOR ILLUSTRATED BULLETIN PC

CHROMALLOY CORPORATION

West Nyack, N. Y. — ELmwood 8-5900

CHROMIZING CORPORATION, HAWTHORNE, CALIFORNIA
PROPELLEX CHEMICAL DIVISION, EDWARDSVILLE, ILLINOIS
ELYRIA FOUNDRY DIVISION, ELYRIA, OHIO
SINTERCAST DIVISION, WEST NYACK, N. Y.
SHUNK MANUFACTURING CO. INC., BUCYRUS, OHIO

Circle 832 on Page 48-B



BATTLESHIP GUN BARREL RE-ENLISTS AT GENERAL ELECTRIC

Molybdenum Electrodes. This pair of 12″ diameter electrodes—from the G-E gun barrel—will be used for consumable electrode vacuum arc melting.

This 16″ gun barrel, from the scrapped U.S.S. Colorado, has a Space-Age job—at General Electric in Cleveland. It's now a hydrostatic pressure chamber, used to cold-form massive pieces from tungsten and molybdenum powder.

PS (for pressed and sintered) Moly and PS Tungsten, and their alloys, are new G-E products, important in today's defense effort and civilian markets.

Here are three ways to use PS powder metallurgy billets, slabs, tubes or preforms made from these refractory metals:

1. Forging and metalworking. Use PS Moly and PS Tungsten in billet and slab form for sheet rolling or forging. High densities: moly 95% minimum, tungsten 92% minimum.

2. Consumable electrode vacuum arc melting. Use electrode bars of moly in diameters 1″ through 12″. Tungsten and moly/tungsten alloys, 1″-9″. High density and high purity (99.9% minimum metal content). Good straightness—no more than 3/16″ camber on a 30″ electrode. With or without carbon additions.

3. Direct machining. For example, crucibles, furnace boats and throat inserts for missiles are machined from PS Tungsten preforms. Order the basic PS material for your own machining or, should you prefer, order the finished part ready to use. If you're looking for controlled density in tungsten, General Electric can vary it between 65% and 95%, plus or minus 3%.

Put PS Moly and PS Tungsten, with their unique high temperature properties, to work now. Call or write Lamp Metals & Components Dept. MP-81, 21800 Tungsten Rd., Cleveland 17, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 833 on Page 48-B

copper brazing, bright annealing of stainless, or hydrogen cleaning of small, complex parts. *American Gas Furnace Co.*

645. Heating Elements

For precise, economical electric heating in brazing or heat treating applications, investigate "Globar" silicon carbide heating elements. *Carborundum Co.*

646. Thermocouples

48 pages of profitable information is contained in the "Ceramo" thermocouple Catalog No. TC-16. *Thermo Electric Co.*

647. Heat Processing

Bulletin 653A details the advantages of electric or fuel-fired heat treating furnaces for a wide variety of applications. *Hevi-Duty Electric Co.*

648. Potentiometers

Minneapolis-Honeywell has released a pamphlet which tells about the "Electronik 17", a small-case potentiometer with modular design.

Finishing

650. Wetting Agents

A full line of wetting agents for diversified industrial uses, including metal processing, is described in booklet published by *Nopco Chemical Co.*

651. Blast-Cleaning Machines

28-p. catalog describes line of "Super Tumblast" batch-type airless abrasive blast cleaning machines. *Wheelabrator.*

652. Surface Treatment

A dry acid salt, "Metex M-662" deoxidizes aluminum alloys for phosphating, anodizing, painting, plating and bright dipping. *MacDermid Inc.*

653. Selective Plating

8-p. brochure describes equipment, techniques and plating jobs performed with the "Dalic" electroplating process. *Sifco Metachemical, Inc.*

654. Titanium Anodes

"Platinum-ized" titanium-mesh anodes give solid platinum anode efficiency and quality performance at one fifth the cost. Information from *Sel-Rex Corp.*

655. Metal Finishing

Turco Products, Inc. has released 12-p. metal finishing brochure which contains specific information on the use of each of its 43 cleaning and processing compounds.

656. Spray Drying of Abrasives

Reprint No. NC from *Bowen Engineering*, discusses spray drying of abrasive (settling tank) fines at Norton Co.

657. Gold Plating

Bulletin 175BT discusses an extra-high purity gold electroplating process called "Temperex HD", for electronic applications. *Sel-Rex Corp.*

658. Sulfuric Acid Pickling

Brochure from *Amchem Products, Inc.* presents the details on "Rodine 23", a formulation designed for faster pickling at low temperature. It exhibits high-foaming, free-rinsing characteristics even at high-iron concentrations.

659. Abrasive Compounds

Bulletin issued by *Roto-Finish Co.* discusses problems in the selection of the right abrasive media and compound for use in vibratory and barrel finishing.

660. Barrel Finishing

96-p. booklet describes various barrel-finishing processes and equipment and presents case histories of actual applications. *Norton Co.*

661. Glass Shot

Microbeads, Inc. will send brochure "The Story of Glass-shot" which discusses microscopic glass beads for industrial blast cleaning and reflective purposes.

662. Aluminum Etch

All "Oakite" alkaline compounds are controlled to provide an identical rate of etching, batch after batch. Information from *Oakite Products, Inc.*

663. Exhaust Fans

Bulletin GP-100 contains details on a line of centrifugal fans for exhausting fumes from chemical laboratories, or handling light dust from polishing wheels and grinders. *General Blower Co.*

Welding

665. Silver Brazing

Pamphlet No. 20 from *Handy & Harman* gives a good picture of silver brazing and its benefits, and includes details on alloys, heating methods, joint design and production techniques.

666. Welding Mild Steel

20-p. brochure tells how to weld mild and low-alloy steels and includes specifications, operating characteristics, mechanical properties and applications. *The McKay Co.*

667. Metal Cladding

Reprint entitled "New Techniques for Cladding With Gas-Shielded Process" by Ralph D. Engel. *Air Reduction Sales Co.*

668. Micro-Wire Welding

For more information on the micro-wire welding process, which welds 50% faster than ordinary methods, send for Catalog DM-159. *Hobart Brothers Co.*

669. Stud Welding

Flyer from *Omark Industries, Inc.* tells about stud-welding equipment for ferrous and nonferrous metals. Strong welds are produced without burn-through or distortion of the work, even on very thin metal.

670. Flame Plating

Linde Co. will send details on tungsten carbide coating for improving wear and abrasion resistance of steel parts.

671. Buttwelding of Pipe

Ohio Crankshaft Co. has published reprint entitled *"Buttwelder Leaves No Flash".*

672. Plasma Spraying

Folder entitled "Plasma Bond Spraying Service" describes applications and fabrication techniques for metallic-ceramic coatings. *Thermal Dynamics Corp.*

673. Electron Beam Welding

The *NRC Equipment Corp.* will send information on electron beam welding, to help solve your tough welding problems.

674. Plasma Coating

12-p. booklet illustrates the plasma coating process, and presents properties and uses of coatings. *Plasmatech Div.*

675. Adhesive Specifications

Minnesota Mining and Mfg. Co. has published 54-p. compilation listing U.S. Government specifications for adhesives, coatings and sealers.

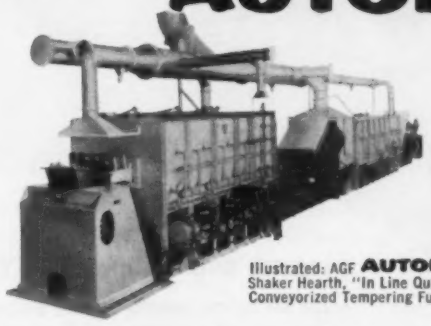
676. Welding Alloy Wall Chart

Welding, brazing and soldering alloys and fluxes are rapidly selected according to the base metal to be joined. *All-State Welding Alloys Co.*

Circle appropriate number on Reply Card, p. 48-B

AGF

AUTOMOTION



Illustrated: AGF **AUTOMOTION** Shaker Hearth, "In Line Quench", and Conveyorized Tempering Furnace.

AUTOMOTION best describes AGF's unique automatic heat treating furnaces . . . both Reciprocating Hearth and Rotary Retort . . . employing the "Work in Motion" principal that assures uniformity of case and hardening.

AGF's **AUTOMOTION** Furnaces operate **wholly automatically** and **continuously,** and are easily placed in any continuous or intermittent production line.

Send for catalogs and details of models to meet your specific needs

AMERICAN GAS FURNACE CO. 1002 LAFAYETTE STREET, ELIZABETH, N. J.

Circle 834 on Page 48-B

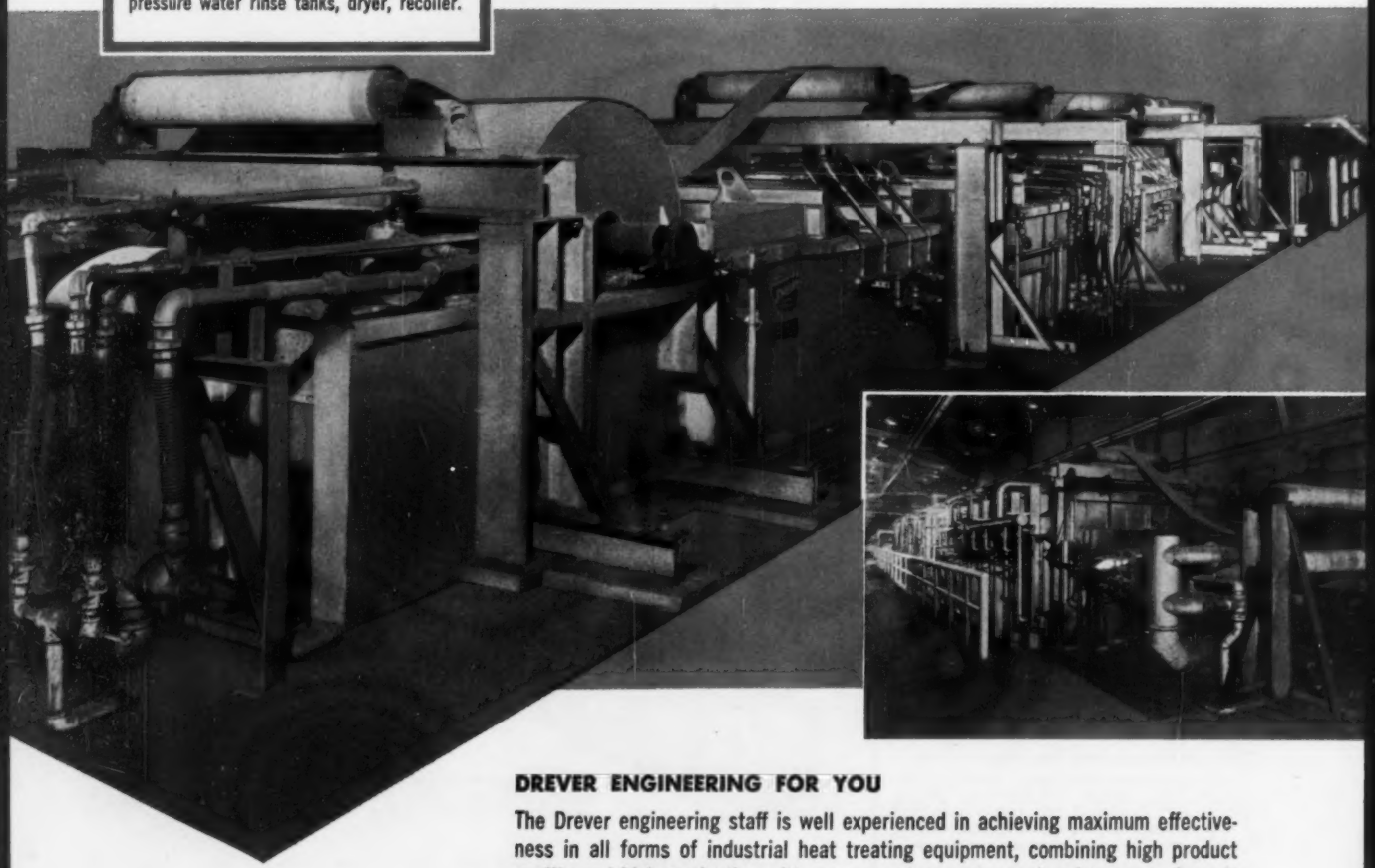
PUTTING A FINE FINISH ON STAINLESS STRIP—

DREVER CONTINUOUS DESCALING SALT BATH

Users of stainless strip are demanding high finishes that reduce their own production problems. To achieve this standard of finish on the heavier gauges of series 300 strip, a Drever Continuous Descaling Salt Bath provides high quality, fast descaling. The strip is immersed in a molten salt bath at controlled temperatures up to 950°F, no atmosphere is required, and speeds up to 150 FPM are attained. Gauges from .018″ to .095″ in widths up to 52″ are handled from coils weighing as much as 10 tons.

Drever designs and builds batch and continuous salt baths for stainless strip, plate, bar, wire or tubing. Or, complete lines providing for continuous annealing and descaling can be engineered to the producers requirements.

This Drever Continuous Descaling Salt Bath receives cold rolled strip at bath temperature from the annealing furnace shown in the smaller picture. Descaling unit consists of salt bath, water quench, acid dip, high pressure water rinse tanks, dryer, recoiler.



DREVER ENGINEERING FOR YOU

The Drever engineering staff is well experienced in achieving maximum effectiveness in all forms of industrial heat treating equipment, combining high product quality and high production with economy of operation and maintenance. Consult with them about your heat treating requirements. Drever Company, Bethayres, Pa. Phone: Wilson 7-3400.

DREVER INDUSTRIAL FURNACES

ENGINEERED TO YOUR PARTICULAR REQUIREMENTS

ENGINEERING AND MANUFACTURING FACILITIES AROUND THE WORLD THROUGH ASSOCIATES IN FRANCE, GREAT BRITAIN, GERMANY, ITALY, JAPAN AND INDIA

Circle 835 on Page 48-B

677. Electron Beam Welding

To learn more about electron beam welding, send for pamphlet issued by *Sciaky Bros., Inc.* Low voltage and redesigned chamber eliminates x-ray hazards.

678. Welding Electrodes

8-p. Folder A-4 presents case history reports on how three companies benefited through the use of *McKay Co.* electrodes and wires.

679. "Arc Welding News"

24-p. Booklet No. 166 contains interesting articles and application photographs on manual and automatic arc-welding processes. *Hobart Brothers Co.*

Testing

680. Metallographic Equipment

William J. Hacker & Co. has released a pamphlet on "Reichert" metallographs which include the following special features: Microhardness testing, high-temperature microscopy and phase contrast metallography.

681. Spectographs

Leaflet from *Jarrell-Ash Co.* discusses a convertible "Ebert" spectograph which can do both routine analyses and the "odd sample".

682. Metallurgical Microscopes

Catalog 2-Q from *Unitron Instrument Co.* describes metallographs and universal camera microscopes.

683. Electrolytic Polisher

Ercona Corp. has released literature illustrating electrolytic polisher which permits constant observation of the etching process.

684. Wiring Terminals

4-p. folder includes photographs and drawings of strain gage wiring terminals, characteristics and specifications as well as features, types and dimensions. *Baldwin-Lima-Hamilton Corp.*

685. Strain Gage

Leaflet from *Metrix, Inc.* covers "Type P-8" a flat-grid polyester-base wire strain gage used at temperatures up to 400° F.

686. Gas Chromatograph

4-p. Bulletin No. 619 describes the "Chronofrac Model VP-1" which gives reliable solutions to routine gas and volatile liquid analysis problems. *Precision Scientific Co.*

687. Sight-Flow Indicator

Pamphlet No. 820 gives details on "Brooksight" flow indicator designed to meet requirements of chemical processing industries (no blind threads). *Brooks Instrument Co., Inc.*

688. Nuclear Review

Spring issue of "Alco Review" contains articles on nuclear power, radiography for weld testing, and a cost study of design variables of heat exchangers. *Alco Products, Inc.*

689. Electrolytic Etching

Information from *Buehler Ltd.* on a self-contained electrolytic etching unit, with a variable d-c. power supply, for the preparation of metallographic specimens.

690. "Edgegraphing"

16-p. data sheet explains Edgegraphing, a new technique for hand analysis of complex engineering data in 10, 20, or more variables. *Statistical Engineering Institute.*

691. Hardness Testing

Reference book containing complete information on hardness testing. Easy-to-read text with many illustrations. *Clark Instrument, Inc.*

692. Testing of Metals

Ten-page Bulletin M-2 from *Instron Engineering Corp.* covers all fields of precision metals testing.

693. "The Laboratory"

32-p. journal features new developments in instruments, apparatus, lab furniture, reagent chemicals, and methodology. *Fisher Scientific Co.*

694. Shock Testers

24-p. Booklet No. 4-70 describes "Hyge" shock testers — precision instruments for simulating shock conditions. *Consolidated Vacuum Corp.*

695. Roundness Measurement

The *Engis Equipment Co.* will send information on "Talyrond", an analysis service for determining roundness, sphericity, concentricity, and coaxiality.

696. Facilities Booklet

Eastman Kodak Co. has released a booklet describing facilities for design, research, and production of systems utilized for photography, optics, electronics, and infrared equipment.

697. Temperature Programmer

Brochure No. 792 details the advantages of the "ThermotraC", a temperature programmer designed for linear or nonlinear laboratory gas chromatography. *Beckman Instruments.*

698. Spectrographic Analysis

Jarrell-Ash Co. will send detailed technical information on the "Compact Atomcounter", a direct-reading polychromator, which can analyze a sample for as many as 22 elements.

699. Research Metallographs

Find out how "B & L" research metallographs can produce faster, easier, completely dependable analyses to help you save time and materials. Catalog E-240, *Bausch & Lomb, Inc.*

700. Load-Cell Systems

12-p. engineering manual R-2 illustrates many uses for remote indicating load-cell systems. *W. C. Dillon & Co.*

701. Grinder and Polisher

Leaflet from *Geoscience Instruments Corp.* contains information on "Uni-Pol", a universal lapping and polishing machine for critical surface preparation.

702. Leak Detector

Pamphlet 24510 describes the "Type 24-510 Radiflo" leak dectector, capable of testing hermetically sealed components for leaks in the 10^{-11} atm. cc/sec range. *Consolidated Electrodynamics.*

703. Optical Pyrometer

When high temperatures are critical, rely on "Pyro-Eye", an automatic two-color optical pyrometer, for precise control. Bulletin 613, *Instrument Development Laboratories.*

704. Portable X-Ray Units

"Fedrex" portable x-ray units are available in 140, 160, 200 and 260 kv. models. *Curtiss Wright Corp.*

705. Testing Machines

Riehle Testing Machines Div. offers pamphlet reviewing complete line of testing machines and accessory equipment.

706. Ultrasonic Inspection

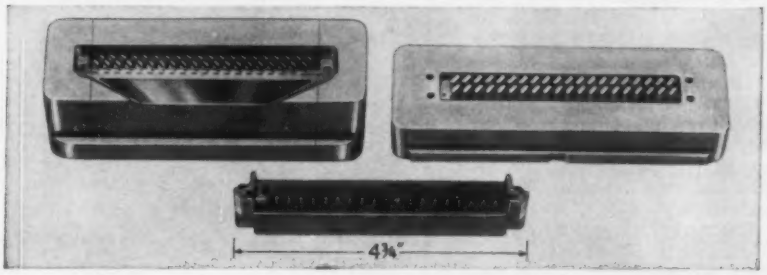
Ultrasonics, Inc. will send brochure discussing the capabilities of modern ultrasonic inspection systems.

707. Microhardness Tester

The *William J. Hacker Co.* has published reprint entitled "A Contribution to the Practical Application of the Microhardness Tester" by L. Willing, Vienna.

Circle appropriate number on Reply Card, p. 48-B

UHB Orvar Tool Steel
Provides High Dimensional Stability



Transfer Mold made by H. Feier Tool and Machine Co., Merchantville, N. J.

With a plastic part this complex, retaining dimensional stability of the transfer mold is important! Elco Corporation, Philadelphia, found UHB Orvar "Superior, even on long sections . . . ". This transfer mold will produce approximately 3 million Diallyl Phthalate plastic electronic connectors, at 25 shots per hour – 3000 psi. The mold cavity was easily machined. Heat treatment brought hardness to Rockwell C 53-55, without deforming or scaling.

UHB Orvar (SAE H-13) is a hot-work tool steel having excellent heat-checking, non-deforming and non-scaling properties – even under rapid heating and cooling cycles.

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Circle 836 on Page 48-B

The 16th METALLOGRAPHIC EXHIBIT

Detroit, October 23 to 27, 1961

All metallographers—
everywhere—
are cordially invited to
display their best work.

RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

Classification of entry.

Material, etchant, magnification and other desirable data.

A brief statement (if desired) calling attention to any unusual aspect of the entry.

The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

Entrants living outside the United States should send their micros by first-class letter mail endorsed "Photo for Exhibition — No Commercial Value — May Be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 10, 1961, either by prepaid express, registered parcel post or first-class letter mail, addressed:

Metallographic Exhibit
American Society for Metals
Metals Park
Novelty, Ohio, U. S. A.

CLASSIFICATION OF MICROS

Class 1. Irons and steels, cast and wrought
Class 2. Stainless steels and heat resisting alloys
Class 3. Aluminum, magnesium, beryllium, titanium and their alloys
Class 4. Copper, nickel, zinc, lead and their alloys
Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements
Class 6. Metals and alloys not otherwise classified
Class 7. Series showing transitions or changes during processing
Class 8. Welds and other joining methods
Class 9. Surface coatings and surface phenomena
Class 10. Slags, inclusions, refractories, cermets and aggregates
Class 11. Electron micrographs using replicas
Class 12. Electron micrographs (transmission)
Class 13. Color prints in any of the above classes
Class 14. Results by unconventional technique

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various Chapters.

43rd NATIONAL METAL CONGRESS & EXPOSITION

Cobo Hall, Detroit——————Oct. 23 to 27, 1961

Circle 837 on page 48-8

713. Diffraction Equipment

For details on RCA's complete line of x-ray diffraction and spectroscopy apparatus or electron microscopes, contact *Radio Corp. of America.*

714. Polishing Desk

Buehler Ltd. has published a pamphlet explaining their polishing desk, which provides maximum efficiency in the production of specimens for the metallurgical laboratory.

715. SR-4 Indicator

6-p. Bulletin No. 4411 presents information on the "Type 110" SR-4 pointer indicator and indicating controller made by *Baldwin-Lima-Hamilton Corp.*

Casting

717. Investment Castings

56-p. bulletin on precision investment casting equipment and supplies is available from *Alexander Saunders & Co.*

718. Mixing Equipment

Brochure B-521 from *Mixing Equipment Co.* describes line of equipment for efficient fluid mixing.

719. High-Temp Vacuum Furnace

NRC Equipment Corp. has issued a specification sheet on the "Model 2914-A" vacuum furnace for heat treating up to 2600° C.

720. Vacuum Pumps

"Series H Microvac" pumps offer more pumping performance per dollar. *F. J. Stokes Corp.*

721. Oxygen Supply

Get the full story on oxygen supply and applications from *Air Reduction Sales.*

722. Refractory Cement

Norton Co. has information on "alundum" aluminum oxide; "Magnorite" magnesium oxide; spinels and "Crystolon" silicon carbide cements.

723. Metal Quality Control

4-p. folder entitled "Automatic X-ray Spectograph Speeds Analyzing of Metals" is available from *Philips Electronic Instruments Div.*

724. Die Casting Machine

The Cleveland Automatic Machine Co. has issued 6-p. Brochure No. 461 which presents detailed specifications and illustrates construction features of the "Model 400" high-pressure hydraulic die casting machine.

725. Vacuum Degassing

Bulletin 300 describes "Vacuum Degassing of Steel in the Ladle Process", as well as the technique of pouring degassed steel through a blanket of argon gas. *A. Finkl & Sons Co.*

726. Meehanite Metal

16-p. brochure entitled "The Case For Meehanite Dies and Molds" presents outstanding applications and properties of the metal. *Meehanite Metal Corp.*

727. Investment Molding

Lebanon Steel Foundry has published a bulletin, "Combining Ceramic and Investment Molding in a Single Casting".

728. Endothermic Generator

Lindberg Engineering Co. offers Bulletin T-200 on its "Hyen" endothermic generator, a fully automatic process for producing low-cost protective atmospheres for bright hardening, bright annealing or brazing of steel.

729. Atmosphere Analyzer

Mine Safety Appliances Co. has issued a bulletin discussing the "Lira Model 300" infrared analyzer for measurement of CO, CO_2, methane, and dewpoint in furnace atmospheres.

737. Electromanganese

Bulletin 201 from *Foote Mineral Co.* discusses electromanganese for producing cleaner, better surface steels at lower cost.

738. Button Furnace

Zak Machine Works will send literature describing their vacuum button furnace, a compact unit for experimentation, quality control, or small production and laboratory melts.

739. Stopper Head

4-p. leaflet from *Vesuvius Crucible Co.* outlines special features of a "Rotolok" stopper head, the first major improvement in stopper rod assembly for steel pouring introduced in the last 30 years.

740. Refractory Maintenance

4-p. reprint covers techniques of refractory maintenance in basic oxygen furnaces. *Harbison-Walker Refractories Co.*

Parts

742. Tubular Products

Bulletin No. 12 from *J. Bishop & Co.* discusses tubular products up to 1 in. O.D. in stainless, nickel, and super-alloys.

743. Decimal Chart

A decimal equivalent chart designed for quick conversion of Birmingham wire gages and fractions to decimals is available from *Ohio Seamless Tube Div.*

744. Precision Springs

Information from *Associated Springs Corp.* describes more than 800 new sizes of precision compression and extension coil springs.

745. Threaded Fasteners

"Friction as a Factor in Bolt Tension, Galling, and Seizing", an 8-p. reprint offered by *Alpha-Molykote Corp.*, covers effect of friction in threaded connections.

746. Guide and Piston Rods

In combination with hardened steel bushings, "Bronze Case" increases life of guide rods and piston rods tenfold. Bulletin lists money-saving advantages, specifications and sizes. *Thomson Industries, Inc.*

747. Wire Cloth

120-p. catalog from *Cambridge Wire Cloth Co.* describes wire cloth made from a wide range of metals including titanium, platinum, lead, stainless steel, or bronze.

748. Self-Aligning Locknut

Leaflet released by *Standard Pressed Steel Co.* reviews a self-aligning locknut, "SPS SA-16", that compensates for out-of-squareness condition as great as 8°.

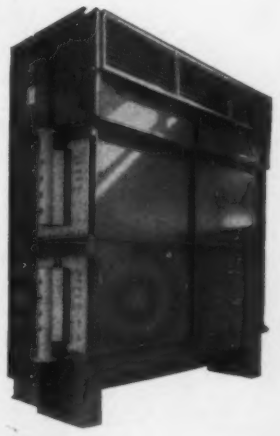
749. Carbon Steel Tubing

Revere Copper and Brass has published a 4-p. leaflet entitled "Electric Resistance Welded Steel Pressure Tubing" which discusses the production and testing of welded tubing for heat transfer uses.

750. Flexible Metal Hose

32-p. illustrated guide published by *Atlantic Metal Hose Co.* is designed to help the engineer select the right flexible metal hose and design for his specific installation.

Circle appropriate number on Reply Card, p. 48-B



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The Niagara *Aero* Heat Exchanger transfers the heat to atmospheric air by evaporative cooling. It extends your quenching capacity without using extra water. It pays for itself with water savings.

You can cool and hold accurately the temperature of all fluids, gases, air, water, oils, solutions, chemicals for processes and coolants for mechanical and electrical equipment. You get closed system cooling, free from dirt and scale.

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Circle 838 on Page 48-B

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Induction Heat Treating
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FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

August, 1961 issue
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Metal Progress August, 1961 Issue

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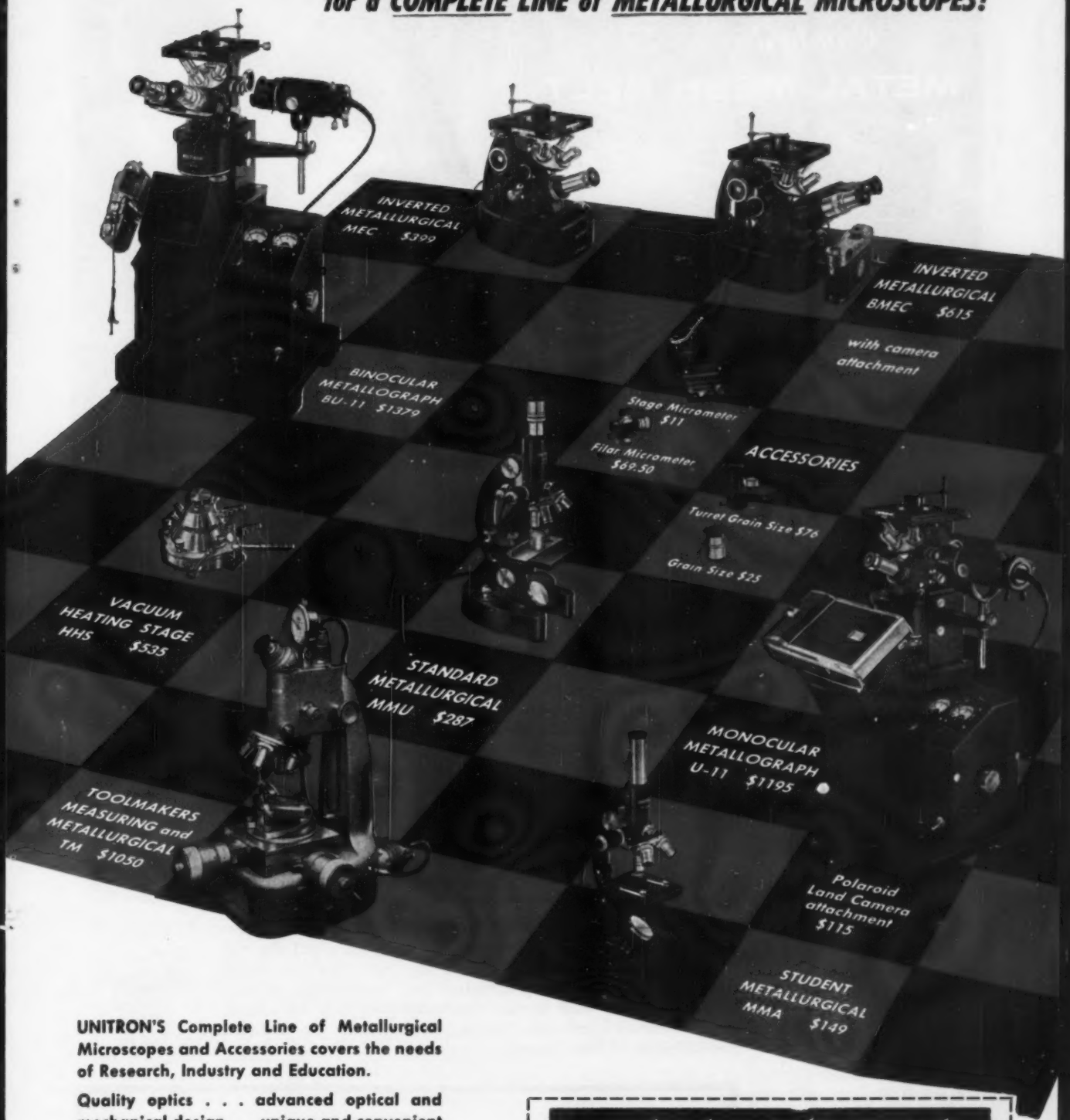

UNITRON'S Complete Line of Metallurgical Microscopes and Accessories covers the needs of Research, Industry and Education.

Quality optics . . . advanced optical and mechanical design . . . unique and convenient operational features . . . budget prices . . . free trial period — these, together with proven performance are the reasons why . . .

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Circle 759 on Page 48-S

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Fights Flux Attack to Cut Brazing Costs

Because of the severe destructive effects of flux used in aluminum and copper brazing processes, proper alloy selection and quality construction are the only answers to long belt life in this type of operation. Cambridge Cambriloy 35-19 Metal-Mesh Belts have successfully withstood flux attack in many copper brazing installations for as long as 6000 hours, giving users continued production of quality parts while cutting operating and maintenance costs.

There is a complete line of Cambridge Belts in special and standard metals and alloys to meet your specific requirements—custom built in any weave to insure the most efficient processing.

Experienced Cambridge Field Engineers—experts in their field—are available to discuss your needs and help you select the best belt suited to your operations. Or, they can offer you sound advice on the installation, operation and maintenance of your Cambridge Belts. Talk to your Cambridge man soon. He's listed in the Yellow Pages under "Belting, Mechanical." Or, write for free 130-page reference manual.

The Cambridge Wire Cloth Co.

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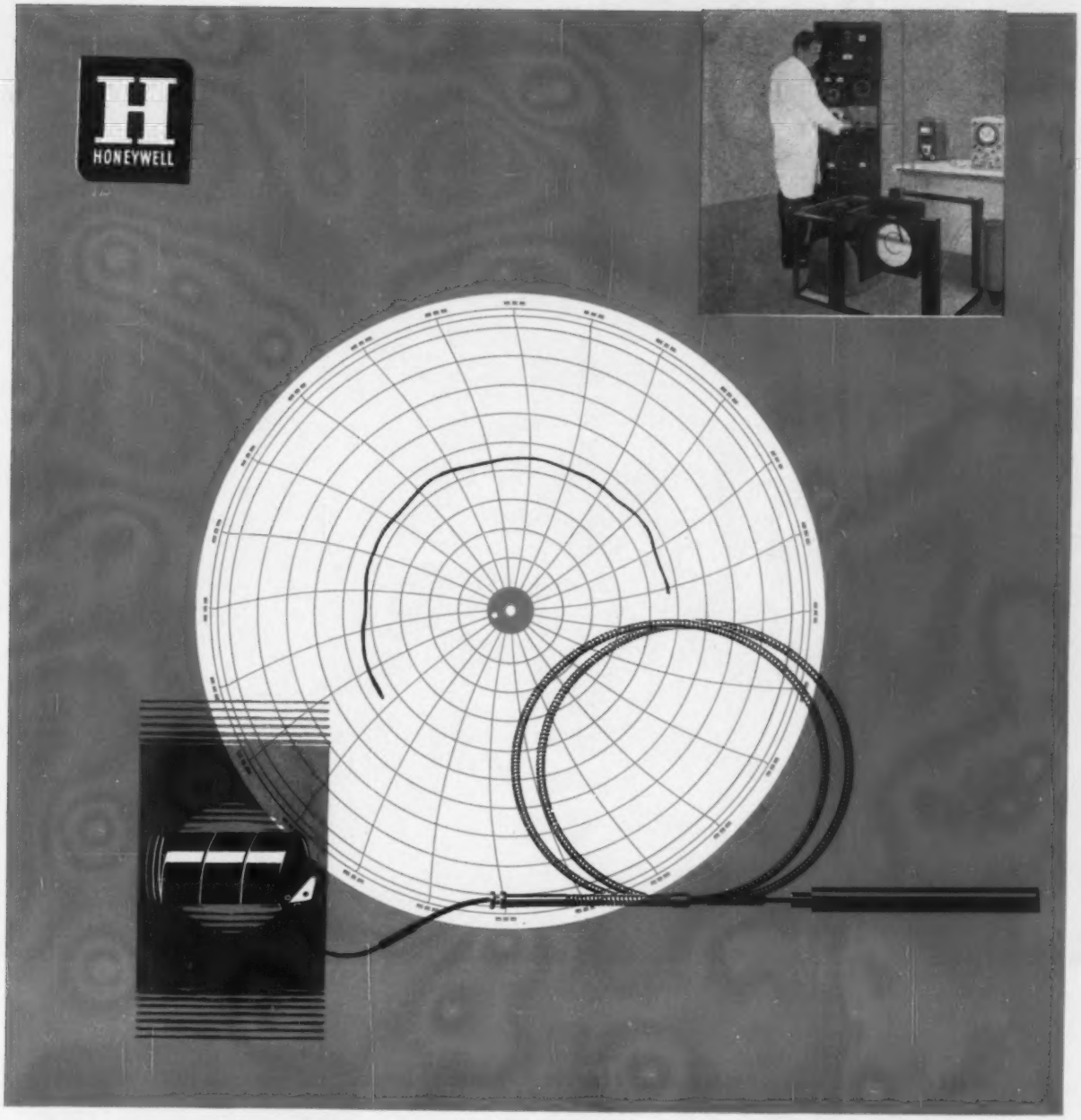
Manufacturers of Metal-Mesh Conveyor Belts, Flat Wire Conveyor Belts, Wire Cloth, Wire Cloth Fabrications, Gripper® Metal-Mesh Slings

Circle 771 on Page 48-B



The New Honeywell Thermal System withstands extreme vibration and corrosion conditions

Here's a new gas-actuated thermal system that takes the zig-and-zag out of temperature recording under severe vibration conditions.

A complete series of vibration tests has proved the vibration resistance of the new Class III thermal system. In these tests (shown above), the Class III system was installed in a standard Honeywell rectangular case recorder, and subjected to forced vibrations in three mutually perpendicular planes. With accelerations up to 0.2G from 0 to 200 cps, maximum pen oscillation was limited to 1.5%. For more than 75% of the range, pen oscillation was less than 0.5%, with no resonant effects at 60 cycles.

Get the complete story by contacting your nearby Honeywell field engineer. Minneapolis-Honeywell, Wayne and Windrim Aves., Phila. 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ont.

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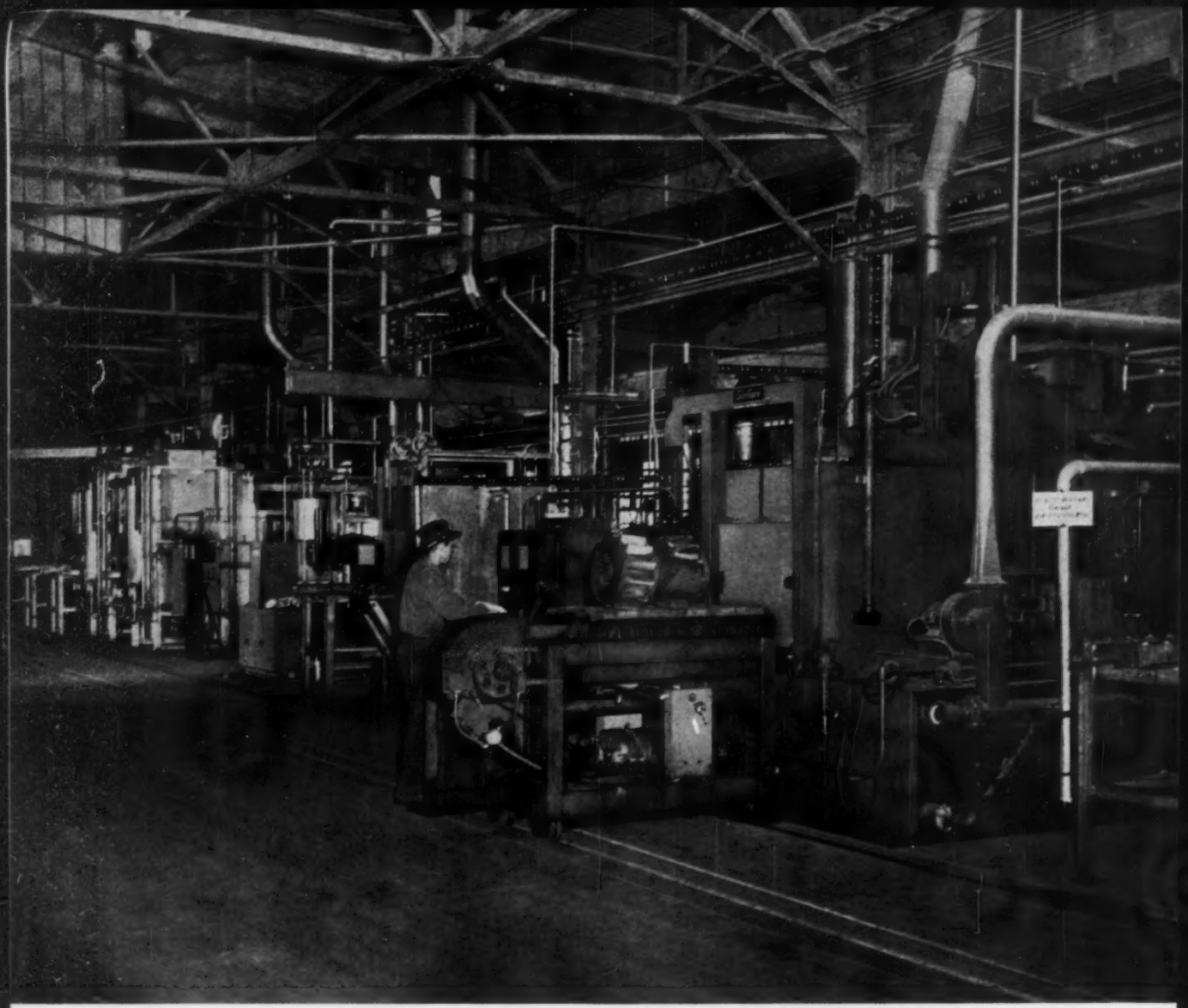
HONEYWELL INTERNATIONAL Sales and Service offices in principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

Circle 761 on Page 48-8



Batch type furnaces form mechanized heat treat line

At The Harnischfeger Corporation, one man can supervise a group of standard heat treat units linked with a shuttle buggy which moves parts quickly and easily from process to process.

Production rate is 460 net pounds per hour of pinions, gears, rollers, shafts, and pins. Chief reason for this is the Surface atmosphere Allcase® furnace. No matter how dense the load, this Power Convection furnace automatically hardens and delivers parts with uniform quality.

Other standard Surface units include two tempering furnaces, two atmosphere generators, and an Autocarb® system which automatically controls the carbon content of gas atmosphere.

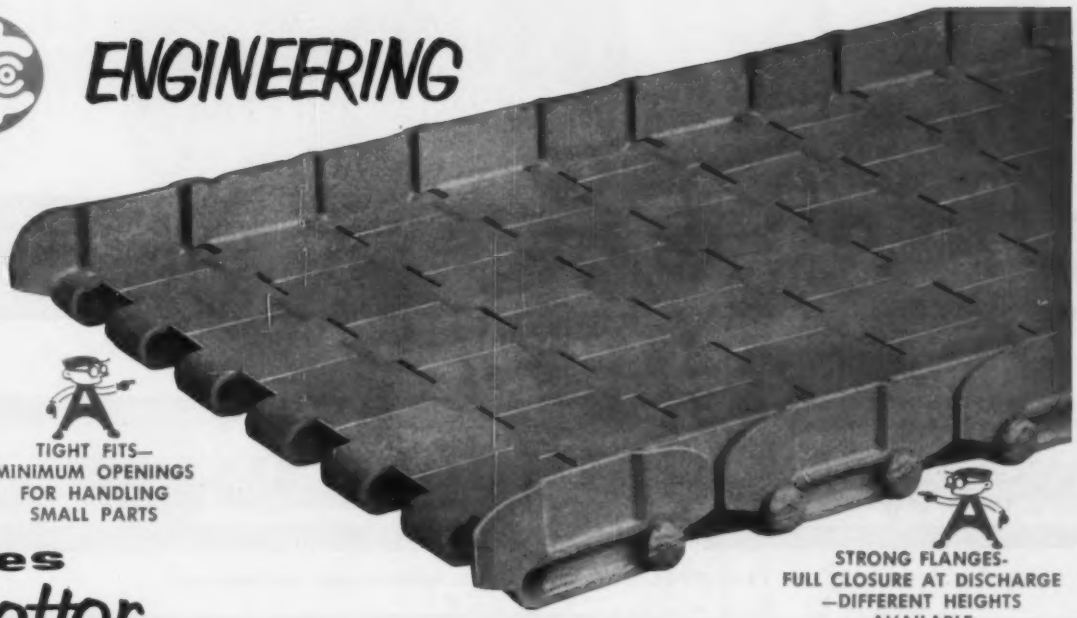
Write for information: 2377 Dorr St., Toledo 1, Ohio. In Canada: 2490 Bloor St., West, Toronto.

SURFACE

SURFACE COMBUSTION, Toledo 1, Ohio/ a division of Midland-Ross Corporation MR

Circle 762 on Page 48-B

ENGINEERING



TIGHT FITS—
MINIMUM OPENINGS
FOR HANDLING
SMALL PARTS

STRONG FLANGES-
FULL CLOSURE AT DISCHARGE
—DIFFERENT HEIGHTS
AVAILABLE

Gives Better Service on.... FURNACE BELTS!

- Improved Proprietary Design
- Better Castings
- Proven Performance

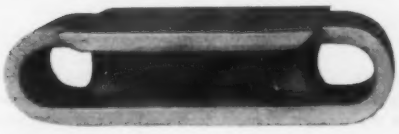
UNIFORM
SECTION
WITH SHARP
DETAIL

PIN SUPPORT AT
CENTER OF LINK FOR
MINIMUM DEFLECTION

The SUPERIOR PERFORMANCE of AECCo. FURNACE BELTS in many customers' plants confirms the advantages of the AECCo. proprietary belt design, and of the advanced casting methods used.

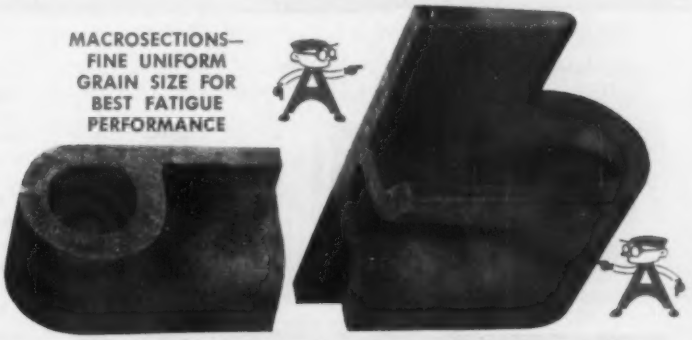
Users report less stretch, less "crankshafting" and maintenance of tighter joints after extended service than with other products.

Drive and idler drums, rollers, skid rails, and any other auxiliary alloy components can also be supplied by AECCo. for best total service of furnace belt installations.



MACROSECTIONS—
FINE UNIFORM
GRAIN SIZE FOR
BEST FATIGUE
PERFORMANCE

DOUBLE RIBS-
BETTER STRENGTH
WITH METAL IN
LINE OF STRESS



EQUAL METAL SECTIONS FOR BALANCED DESIGN

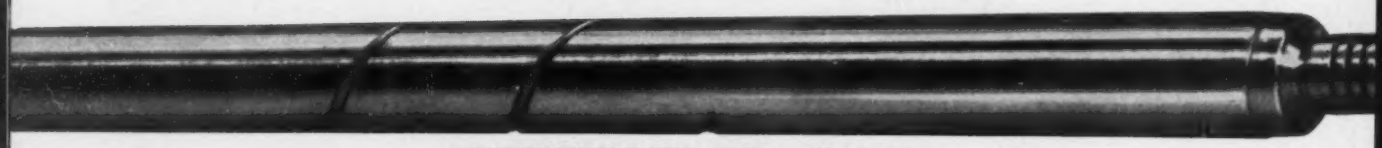
HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ALLOY ENGINEERING & CASTING CO.

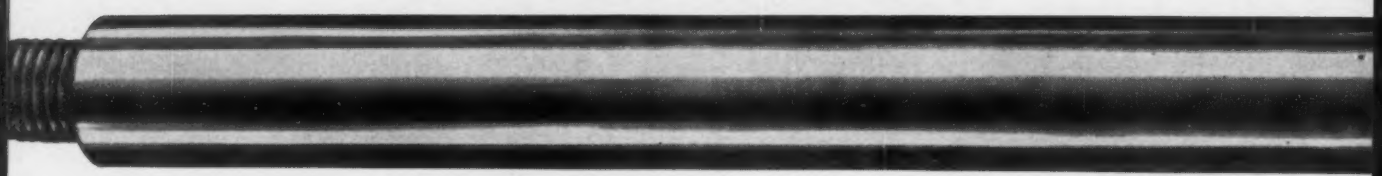
1700 W. Washington St., Champaign, Ill. • Tel: Fleetwood 6-2568

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

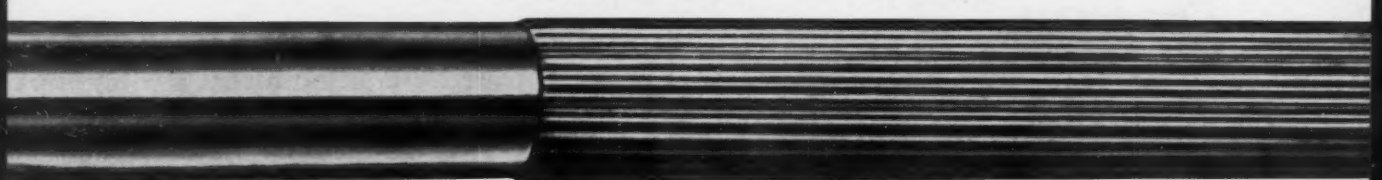
Circle 763 on Page 48-B



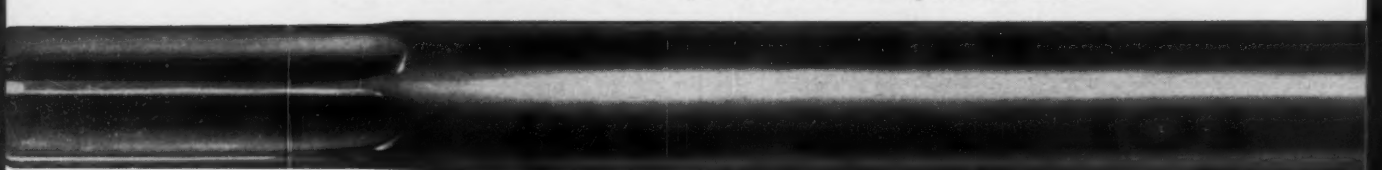
CENTURY SERIES C-1144 for highly machined parts.

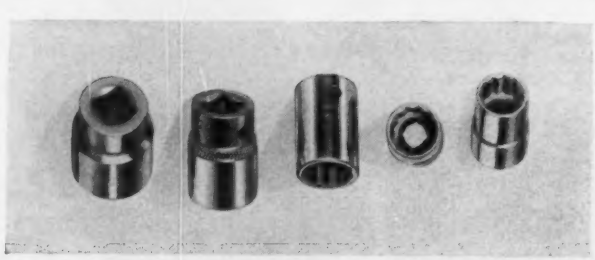


CENTURY SERIES C-1141 and C-1151 for moderately machined parts.



CENTURY SERIES C-1050 and C-1045 for parts where machinability is a minor factor.





WRENCH SOCKETS, made by Herbrand Division of The Bingham-Herbrand Corporation, Fremont, Ohio, illustrate the kind of application where the superior strength, toughness, and machinability of *Republic Cold Finished Alloy Bars* help produce a better product at lower cost.

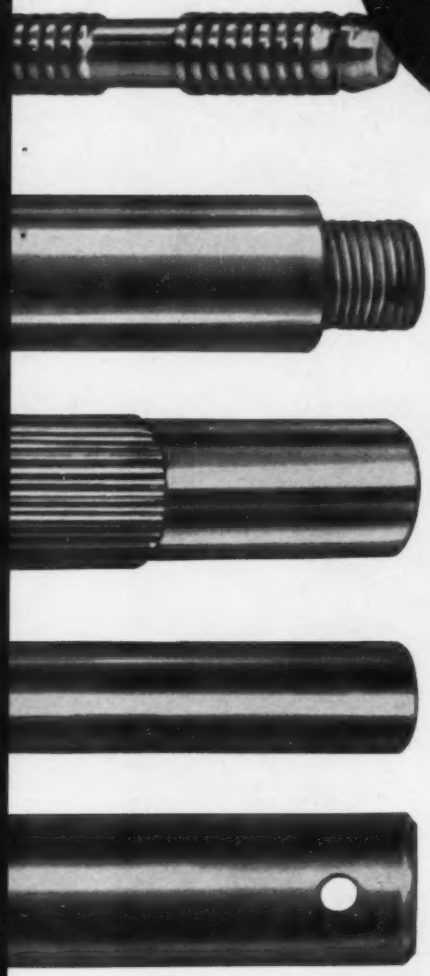
Bars are formed, drilled, and cut off in an automatic screw machine, then hot broached to shape internal dimensions. Final stages of socket production include heat treat and chrome plating. Mail coupon for more data on Republic Alloy Bars.

ROTOR BUCKETS for Mechanical Drive Turbines manufactured by Elliott Co., Jeannette, Pa., are produced from *Republic Stainless Steel Special Sections* . . . an excellent example of how Republic Special Sections save money on tough-to-make parts.

User benefits include: simplified machining, corrosion and abrasion resistance, greater strength and hardness, smooth surfaces that reduce or eliminate finishing operations. Available in a wide range of sizes and contours . . . carbon, alloy, stainless steel, and titanium. Send coupon.

Steel

Strong, Modern, Dependable



Cut Material Costs on High Strength Parts

Republic CENTURY 100 SERIES Cold Finished Bars

LET YOU CHOOSE FROM 5 GRADES, 5 DEGREES OF MACHINABILITY, 5 PRICE LEVELS

With Republic's CENTURY SERIES of high strength, stress relief annealed, cold finished steel bars, you pay only for the machinability you need to meet your production requirements. CENTURY SERIES bars are priced on a descending scale (as machinability decreases, price drops). This makes it possible for you to realize important savings by selecting lower-sulphur-content, high-strength-toughness-ratio bars for applications where machinability is not of prime importance. Each of the five grades has a minimum yield strength of 100,000 psi.

PRODUCTION FACILITIES for CENTURY SERIES bars are strategically located in key metalworking markets to serve you better. Result: faster deliveries, and expert metallurgical service, *when you need it,* on the complete line of Republic Cold Finished Steel Bars. For more information on CENTURY SERIES bars and Republic Metallurgical Services, send the attached coupon.

REPUBLIC STEEL

REPUBLIC HAS THE FEEL FOR MODERN STEEL

Circle 764 on Page 48-B

REPUBLIC STEEL CORPORATION
DEPT. MP-1565-B
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Send more information on:

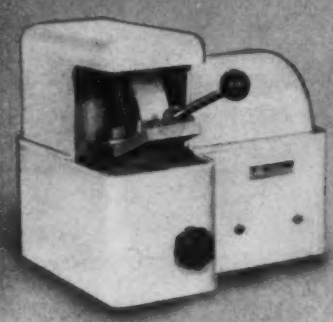
- ☐ CENTURY SERIES
- ☐ Cold Finished Stainless Steel
- ☐ Cold Drawn Special Sections
- ☐ Cold Finished Alloy Steel

Name_____ Title_____

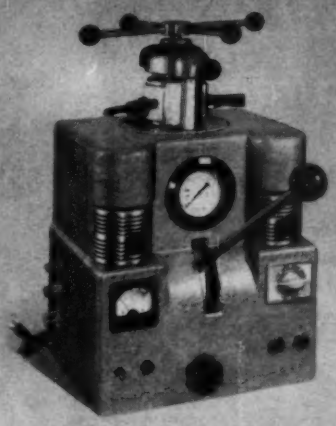
Company_____

Address_____

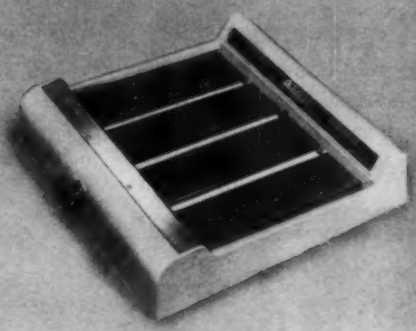
City_____ Zone____ State_____



1114 AB Cutter



1330 AB Speed Press



1470 AB Handimet Grinder

Everything for METALLOGRAPHY

1114 AB Cutter — The ideal wet abrasive cut-off machine for laboratory work on stock up to ½". It is specially designed for the metallurgist for precision, speed and economy.

1330 AB Speed Press — Rapid production of perfectly mounted samples, achieved only with the unique preheated premolds, removes another laboratory bottleneck.

1470 AB Handimet Grinder — Four stages of fine grinding are accomplished with speed and facility on the Handimet. It makes the most of modern grinding methods.

1500 AB Standard Polisher — This is the most popular metallographic polisher ever built. It has direct 2 speed drive, accurate balance, quick change wheels and is easy to clean.

1905-2 AB Automet Attachment — High quality micro-sections are produced by this unit with great savings of time to the operator. Fits all Buehler Low Speed Polishers.

1720 AB Electro-Polisher — With this unit, electro polishing becomes routine. Design and materials are selected for simplicity of operation and minimum maintenance.

The above are a few of the popular models from our complete line of metallographic sample preparation equipment. Many other models and types are available for your selection. Buehler equipment is designed and built according to suggestions from prominent metallurgists in America and throughout the world and is backed by 25 years of service to your industry.

1500 AB Standard Polisher

1905-2 AB Automet Attachment

1720 AB Electro-Polisher

Buehler Ltd.

METALLURGICAL APPARATUS

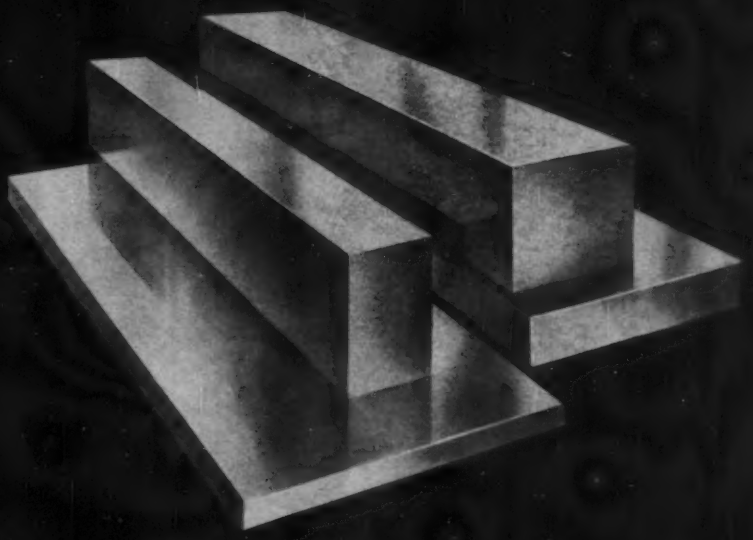
2120 GREENWOOD ST. EVANSTON, ILLINOIS, U. S. A.

Circle 765 on Page 48-B

ANNOUNCING

THE CREAM OF PERFORMANCE

IN PRECISION GROUND STEELS



Ohio Die

Precision Ground—high carbon, high chromium die steel

The wedding of OHIO DIE and the advantages of Precision Ground steel brings to every toolroom new convenience—new utility—new economy in the employment of one of America's great die steels.

This favorite high carbon, high chromium steel is now available precision ground to a finish of 30 micro-inches or better; sides flat and parallel; corners true and square. Each piece is packaged individually in a rust-preventive envelope, plainly marked for size and with clear heat-treating instructions.

OHIO DIE is stocked in a wide range of sizes in all our district warehouses. Call for prompt delivery!

FIRST QUALITY · TOOL & SPECIAL STEELS · V·A

VANADIUM-ALLOYS STEEL COMPANY

GENERAL OFFICES: LATROBE, PA.

DIVISIONS: Anchor Drawn Steel Co. • Colonial Steel Co. • Metal Forming Corporation • Pittsburgh Tool Steel Wire Co. • Vanadium-Alloys Steel Co.

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Circle 766 on Page 48-8

NEW, COMPACT LOW COST L&N PORTABLE POTENTIOMETERS

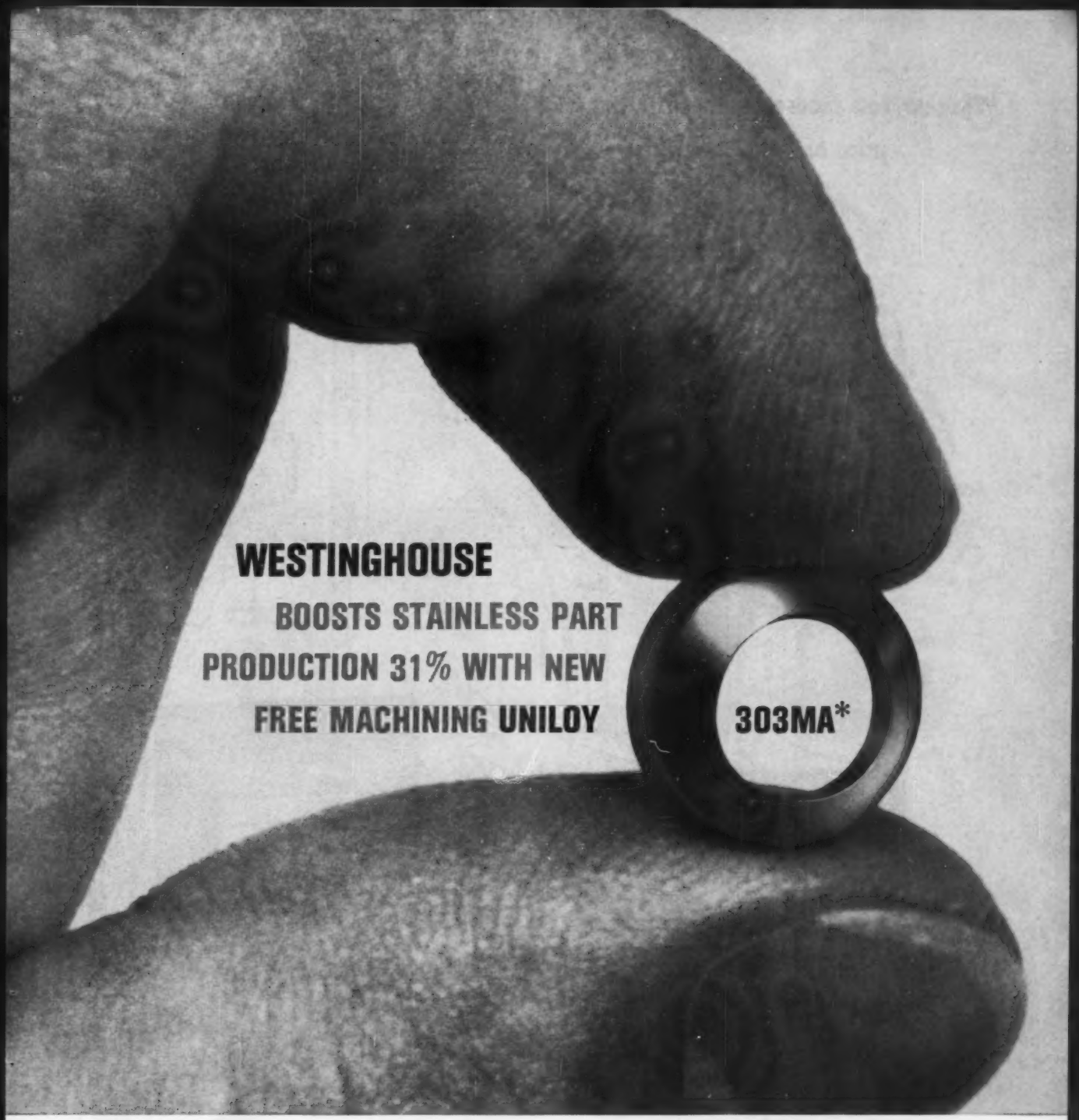
If you check thermocouples, recorders or controllers in plant or lab and are tired of lugging around an oversize instrument just to get the precision you need, you'll welcome one of L&N's three new portable—*really* portable—potentiometers. All the essentials—galvanometer, battery, standard cell—are compactly housed in a 7″ x 6″ x 5″ case . . . and weigh only 4½ pounds. An 8694 Single-Range and an 8695 Double-Range Potentiometer read directly in degrees in any of 15 temperature ranges. An 8696 Potentiometer reads directly in millivolts on two ranges, 0 to 22 and 20 to 64 . . . has a manual reference junction compensation dial, and can be used as a source of calibrated voltage for checking other potentiometer-type instruments.

Get the full story on these new compact instruments—*and* their compact price (starting at $200.00). Just phone your nearest L&N Office, or write for Data Sheet E-33(5) from Leeds & Northrup Company, 4927 Stenton Ave., Philadelphia 44, Pa.

LEEDS & NORTHRUP

Pioneers in Precision

Circle 767 on Page 48-B



The Westinghouse Standard Control Division at Beaver, Pa., compared New free machining Uniloy 303MA* stainless steel with regular Type 303. The part—a close tolerance spring end support for circuit breakers and control equipment—was machined from ½-inch stock. Here are the production line results:

	AISI Type 303	New Uniloy 303MA
Spindle Speed	890	1180
Surface Ft. per Min.	115	155
No. Pieces per Hour	110	144
Tool Life	Form tool sharpened 3 times every 8 hours	Form tool sharpened once every 6 hours

New Uniloy 303MA also machined cleaner and smoother to produce higher quality parts. It is now specified in all applications formerly calling for Type 303 stainless steel at this plant.

Cut *your* production costs! Order New Uniloy 303MA at your nearest Universal-Cyclops steel service center or sales office. Ask for your copy of the "Uniloy 303MA" brochure.

UNIVERSAL CYCLOPS
UC STEEL
STEEL CORPORATION
EXECUTIVE OFFICES: BRIDGEVILLE, PA.

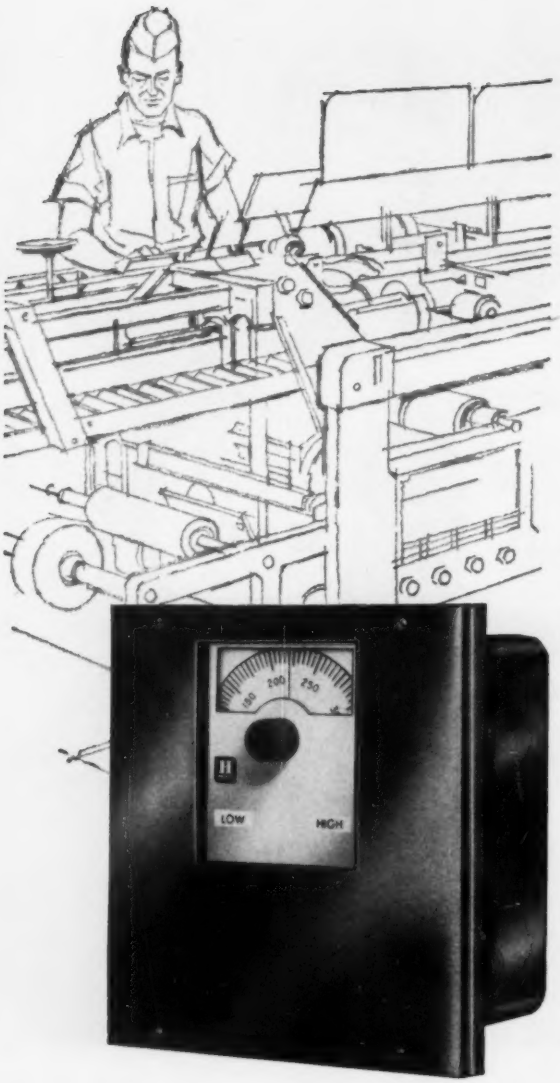
*U.S. PATENT NO. 2,900,250

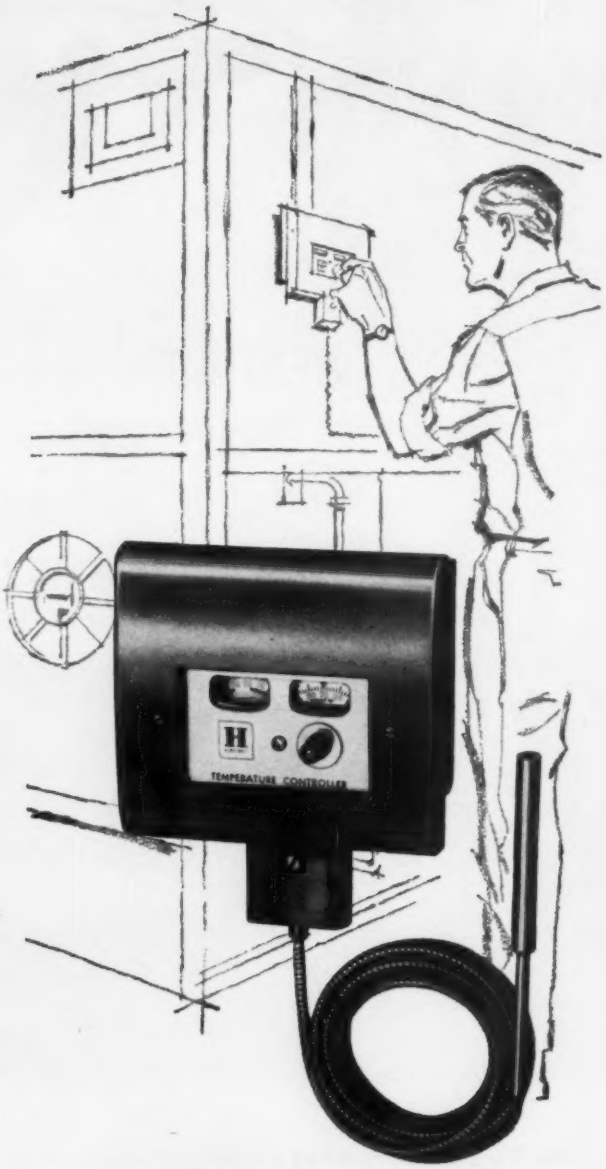
STAINLESS STEELS / TOOL STEELS / HIGH TEMPERATURE AND REFRACTORY METALS

Circle 768 on Page 48-B

Whether you choose by specification, price or both...

There's a Honeywell pressure control





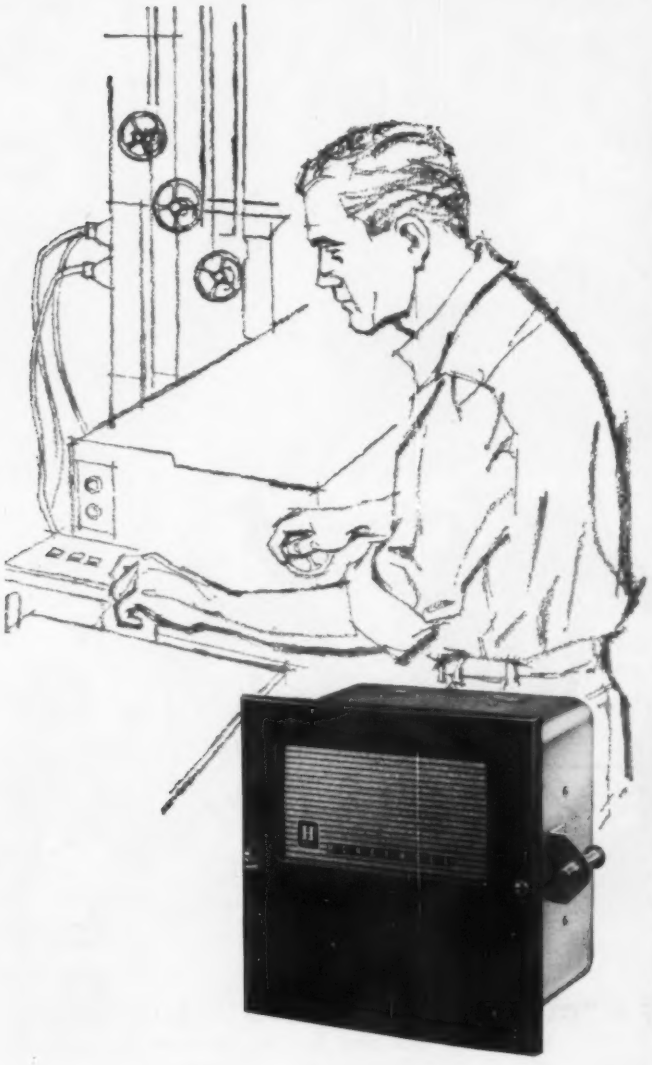
☐ For precise control at low cost—R7086—R7087

Temperature controllers for use wherever precision temperature control must be maintained. Ranges from −150° to +3000° F. are possible. R7086 uses thermocouple, R7087 uses resistance bulb. Both, surface or flush mounted. R7086 $150.00; R7087 *only $120.00.*

☐ For accurate control with indication at low cost

T654A indicates and controls temperatures on an evenly graduated scale accurate within 1% of scale range. This switch can control an *Actionator**, motor, relay, contactor or other device. Completely compensates for ambient temperature changes. Ranges from −150° F. to 1200° F.

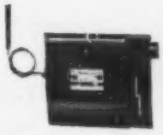
temperature or to fit your exact needs!



Whatever your application, you'll find the control that suits you best in Honeywell's complete selection

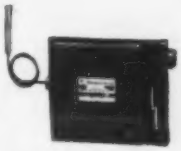
P444

For industrial applications that call for independent high-pressure and low-pressure settings and switching action. Adaptable for surface or flush mounting.



T444

For a wide variety of industrial applications requiring independent high-temperature and low-temperature settings and switching action. Adaptable for surface or flush mounting. Ranges from 0° F. to 660° F.



P428

For general industrial applications requiring the control or limiting of relatively high pressures. Models are made with explosion-proof case for hazardous locations. Ranges from 30 PSI to 5000 PSI.

T667

Designed for use as a remote-bulb temperature controller. SPDT switching provides temperature control in heating, cooling, or heating-cooling commercial and/or industrial applications. Ranges from —150° F. to 1200° F.

**Trademark*

☐ For reliable control at minimum cost—VERSA-TRAN

This inexpensive controller is completely transistorized. Needs no tubes, no warm-ups . . . gives instant reaction. Works with sensors that can be thermisters, probes, resistance bulbs, pressure transducers or humidity elements. Available in various temperature, humidity and pressure ranges. *Standard models as low as $39.50.* Model shown above only $49.50.

Write Honeywell, Minneapolis 8, Minn.

HONEYWELL INTERNATIONAL Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

Honeywell

First in Control

SINCE 1885

Circle 769 on Page 48-B

Where maximum cleanliness is a "must"... EXLO® "75" Extra high in chromium and extra low in carbon, EXLO "75" is specially designed for use in very low-carbon stainless steels and heat-resistant alloys. There are two grades to choose from—.015% max. carbon and .025% max. carbon—both of which contain a minimum of 75% chromium. Because of its exceptional cleanliness, EXLO "75" is particularly adaptable to vacuum melting and other processes requiring minimum contaminant elements.

And don't forget the EXLO Standard Grades for use in low-carbon stainless and heat-resistant steels, irons and alloys. Like all EXLO ferrochromium alloys, they have high density and maximum cleanliness. Write for information or call your nearest VCA District Office. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N.Y. · Chicago · Cleveland · Detroit · Pittsburgh.

VANADIUM CORPORATION OF AMERICA
Producers of alloys, metals and chemicals

Circle 770 on Page 48-B

Cut your production costs!

WELD 3 WAYS with HOBART automatic EQUIPMENT

SO VERSATILE you can use it for—

1. **INERT GAS** The basic unit welds aluminum, stainless, monel, inconel, steel and other metals.
2. **CARBON DIOXIDE (CO_2)** Just change to waterless side delivery nozzle (at left) for welding steel and some alloys.
3. **SUBMERGED ARC** Add this flux hopper for welding steel and alloys.

Select your welding process by simply switching components. Choose the method most suitable for your production schedule. Results are amazing. Welds are uniform time after time, and there's no need to use highly skilled operators.

No. 2 CO_2 Nozzle and No. 3 Flux Hopper are optional components at slight extra cost.

HOBART BROTHERS CO., BOX MM-81, TROY, O. Phone FE 2-1223, *"Manufacturers of the world's most complete line of arc welding equipment."*

YOU CAN SELECT A COMPLETE "PACKAGE" FROM HOBART

It pays to use equipment that's easy to adapt to your particular work. Hobart's automatic equipment "package" is the finest available: A constant voltage welding machine and power source. Automatic wire-feeder and controls. Complete accessories. Automatic welding wires and submerged arc fluxes.

Circle 760 on Page 48-B

CLIP AND MAIL TODAY, FOR MORE INFORMATION

HOBART BROTHERS COMPANY, BOX MM-81, TROY, OHIO

☐ I'd like to know more about Hobart's new versatile automatic welding equipment. I'm particularly interested in: ☐ Inert Gas Welding ☐ CO_2 Welding ☐ Submerged Arc Welding ☐ Automatic Wire ☐ Submerged Arc Flux.

Name_____

Our work is_____

Company_____

Street_____

City_____ Zone____ State_____

150 OPENINGS BURNED IN HUGE CONTROL PANEL ASSEMBLY

Expert Ryerson flame-cutters had to exercise their greatest skill in cutting these openings with a degree of accuracy that would assure proper installation of a complex instrument system. Distortion had to be carefully controlled and a high degree of flatness maintained so that the plates would have a good appearance when painted. These exacting requirements were readily met by Ryerson.

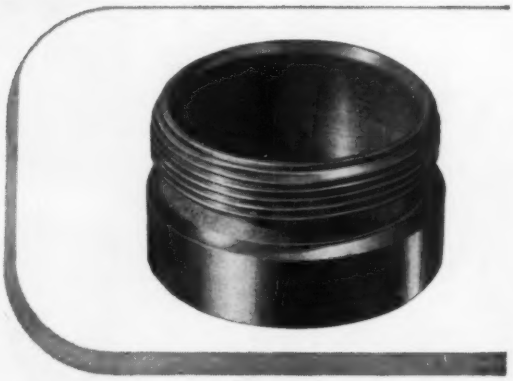
How METALOGICS* cools off the high-cost hot seat!

Here are two examples of how Ryerson Metalogics helps hundreds of companies save money, improve their products and cut costs.

Metalogics-trained Ryerson specialists help you value-analyze high-cost production problems—and give you unbiased recommendations on exactly the right steel, aluminum or plastic, plus the best methods of fabrication, to do the job.

Little wonder, then, that more and more companies across the country find the high-cost hot seat a little cooler after inviting a Ryerson man to value-analyze specific problems and come up with recommendations. Is your company taking full advantage of this unique service?

*Metalogics—the Ryerson science of giving optimum value for every purchasing dollar.



SUGGESTION ELIMINATES THREAD GALLING

Manufacturer made this special coupling of aluminum to gain the advantages of light weight, corrosion resistance and easy machining. But galling of threads presented a problem.

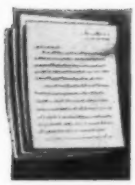
Following the recommendation of a Ryerson Metalogics specialist, the company hard-coated the parts by special low-temperature anodizing, which produced a surface hardness of Rockwell 70 C. Galling was eliminated, and corrosion resistance increased. One more example of cost-cutting technical help from Ryerson.

RYERSON METALOGICS

JOSEPH T. RYERSON & SON, INC., MEMBER OF THE INLAND STEEL FAMILY

STEEL • ALUMINUM • PLASTICS • METALWORKING MACHINERY

Circle 772 on page 48-B

METAL PROGRESS
THE MAGAZINE OF MATERIALS AND PROCESS ENGINEERING
Vol. 80, No. 2 August 1961

Critical Points

By the EDITORS

What the Atom Can Do for You in Testing

AMERICAN INDUSTRY IS HARNESSING the atom in new ways almost every day to make manufacturing more profitable through improved methods of nondestructive testing and process control. Today, over 1700 industrial firms, including the nation's largest, have been licensed to use radio-isotopes for one or more purposes. Over 6000 nuclear gages control the quality of a wide range of consumer and industrial products on hundreds of production lines. Over 450 firms use radio-isotope gamma emitters to perform radiography in their own operations or as a service to others.

"Yet we in the A.E.C. do not believe that more than a fraction of the potential benefits of radio-isotopes have been realized." Thus, spoke Paul C. Aebersold, director of A.E.C.'s Office of Isotopes Development in a presentation made with Oscar M. Bizzell, chief of the Isotope Technology Development Branch before the Society for Nondestructive Testing at the Western Metals Congress in Los Angeles.

It was this growing awareness of the undeveloped potential of radio-isotope and radiation applications that led the A.E.C. to establish a formal Isotopes Development Program. This program does not engage in basic research nor is it concerned with producing fully engineered devices. Instead, it attempts to reduce the time lag between conception of a new principle and its practical application by generating a broad technological base for the use of radio-isotopes and radiation in industry.

Radio-isotopes and the types of radiation they provide can be used for testing in a number of ways – as tracers, in radiography, in gaging and in a variety of unique applications which offer unusual potential for industrial progress. Gamma gaging is used to measure thickness of hot steel strip and tubes. The sensitivity of control systems in such applications is being improved by the development of scintillation detectors for industrial use. Progress in this area is expected to lead to much wider utilization of gamma thickness gages.

Simultaneous measurement of the transmission of two gamma rays of different energy, as from cobalt 60 and cesium 137, can provide control information on processes in which two materials are combined. A potential use is in plating or cladding of one metal with another.

Current developments in beta gage technology include the application of tritium, krypton 85 and promethium 147 which offer new energy levels for inspecting a greater range of materials. Secondary x-rays offer new possibilities in nondestructive testing of thin materials. The broad potential for use of neutrons in industrial testing and process control remains largely untapped. (Additional applications for radio-isotopes in testing and control are discussed on p. 88.)

The editors recall that in 1958 the U. S. Atomic Energy Commission estimated that the use of radio-isotopes was saving U. S. industry some $500 million a year. This was equal to a 7% dividend on the $7 billion the government had invested in atomic energy plants up to that time. Is your company sharing in this dividend and are you alert to the new utility of isotopic methods for solving problems in testing and process control in your plant?

High-Energy Forming

How to Design for Explosive Forming

By VERNON H. MONTEIL*

The process is not a cure-all for forming difficulties but is a good supplemental technique that is useful in shaping difficult materials and large parts. With explosive forming, designers can expect decreased die costs when short production runs are planned.
(G-general; NM-k34, 17-51)

EXPLOSIVE FORMING HAS EVOLVED as one of the most dramatic of the new metalworking techniques. Instead of forming with a punch or diaphragm as in a conventional machine, this process employs an explosive charge. The charge used is very small, but it is capable of exerting tremendous forces on the workpiece. Since the explosive forces are so large and the detonation pressures are developed so rapidly, the forming rate is usually from 250 to 500 ft. per sec. These conditions of extremely high forces and rapid forming rates cause many of the peculiar advantages and disadvantages of explosive forming.

Why Use Explosive Forming?

In the early stages of explosive forming, its most important use was in production of parts which were very difficult or expensive to form by conventional methods. Although the large forces attainable with explosives give the method a definite advantage in forming some parts of this type, the greatest advantages lie in making parts specifically designed for explosive forming. There is, for example, no advantage in explosive forming for long production runs or parts which are designed for and easily formed on conventional equipment. However, it may be used to form a completed assembly in place of a number of subassemblies; here it shows definite economic advantage.

A major consideration in designing for explosive forming is, of course, the characteristics of the material from which the part is to be made. Some knowledge of the relative formability of each new alloy – compared to some basic metal –is a great aid when considering the potential of explosive forming for making a part. Figure 1 is an example of this type of data. Data of this kind are certainly not intended to indicate what metals can and cannot be explosively formed; they do, however, shed some light on the relative weight of explosive charge required for various materials.

Design Considerations

Probably the most important item for the designer who is considering explosive forming is the explosive charge. The explosive is merely a source of energy – the same as supplied by any forming machine. However, because of their nature, explosives provide a highly concentrated source of energy. For example, a 2-oz. charge will do the work of a 10-ton press on a small part, and the work of a 40-ton press on a part twice as large. Furthermore, explo-

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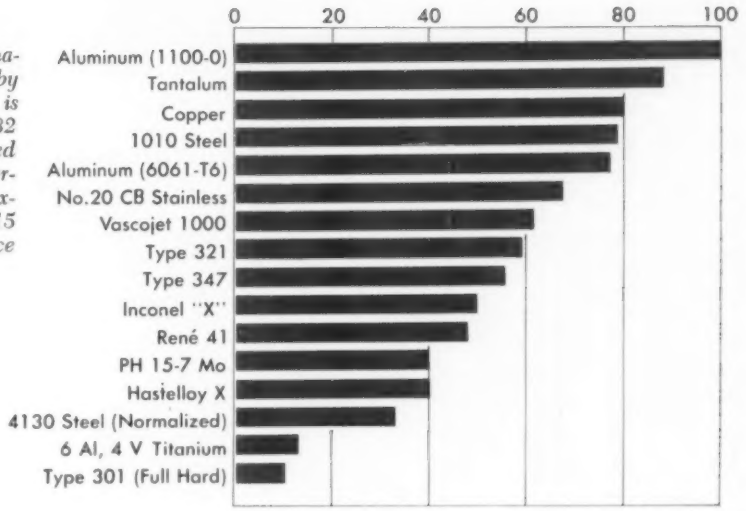


Fig. 1 – Relative Formability of Various Alloys by Explosives. Comparison is based on material 0.032 in. thick in the annealed condition unless otherwise indicated. The explosive was detonated 15 in. from each workpiece

sives can be put into a very small space (as small as 0.1-in. inside diameter) to accomplish this work. The explosive may be placed in almost any position to form the part as desired. No longer is it necessary to build a die to fit a machine and to move the die and workpiece to the machine for forming. The explosive (generally less than 1 lb. and costing about $0.50) can easily be moved to the workpiece for forming; yet any desired load can be applied. By using the proper charge weight, shape and position, almost unlimited forces may be obtained.

Fewer Dies Needed

In its present state of development, the forming cycle for explosive forming is usually longer than that required on conventional machines, particularly for long production runs of small, simple parts. However, as the number of parts decreases and the size increases, the cost of explosive forming remains nearly constant while the cost per part for conventional forming goes up appreciably. This is especially true for parts requiring matched male and female dies for conventional forming. Only a single female die is required in the explosive technique.

Better Control of Thickness

For normal explosive forming operations, the ordinary limits of material elongation and minimum bend radii may be used as a rule of thumb. Material thinning is generally similar to that obtained during conventional forming except that more control is possible. Quite often it is possible to gather material or to apply a more uniform load to a workpiece during explosive forming. Thus, thinning of a deep part can be reduced and sections of nearly uniform thickness can be made.

Close Tolerances Possible

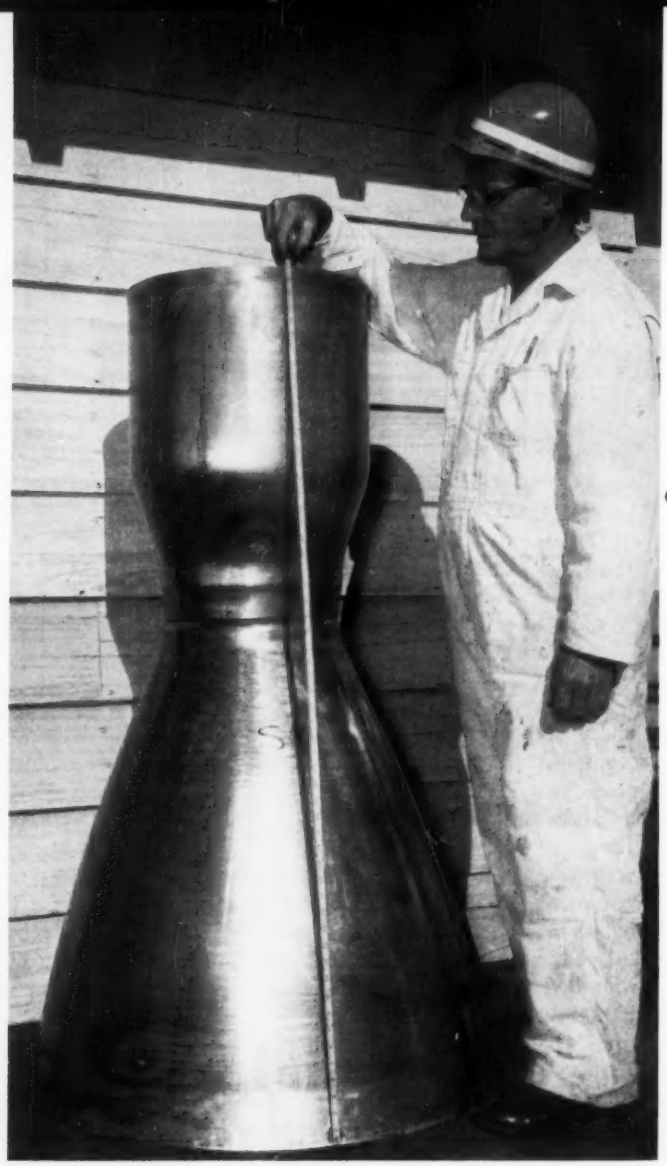
Ordinary tolerances for explosive forming are of the order of ±1/32 in. Such parts can be formed quite rapidly and easily. Close tolerances down to ±0.001 in. are also easily obtained, but a longer forming cycle and better dies are needed.

Finally, in bulging operations, one of two choices is open to the designer. If a part has sufficient draft to allow it to be removed from a one-piece die, the forming operation is simple and the die is relatively inexpensive. Draft is particularly important for parts requiring close tolerance. If for some reason the part cannot be removed from a one-piece die, it is necessary to use a split die which requires more fabrication time and lengthens the forming cycle.

What Parts Can Be Made?

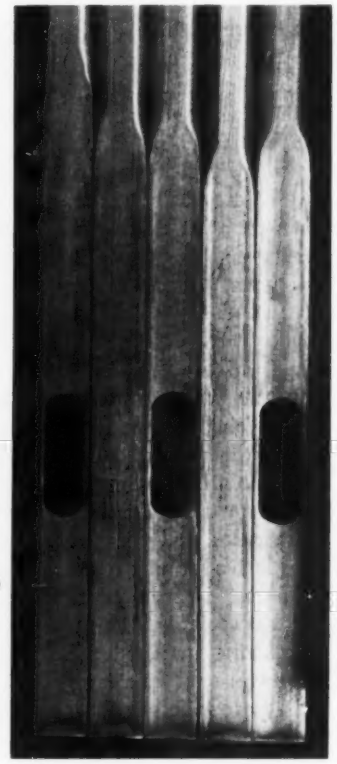
To show some of the important design considerations, a number of general applications are illustrated on the next pages. It should be remembered that explosive forming is a supplement to conventional forming techniques, and is by no means a cure-all for forming problems. Each of the illustrations demonstrates only one design consideration, but it should be kept in mind that in designing a part for explosive forming, several advantages inherent to explosive formed parts may be included in one design. For example, one operation may be all that is required to form, neck and clad an unsymmetrical aluminum shape.

More on Designs for Explosive Forming ▶



Where to Design for Explosive Forming

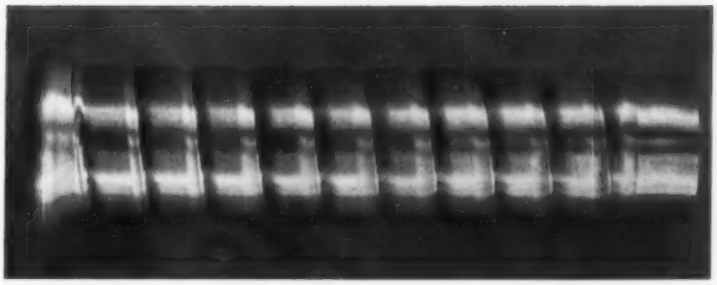
This Is a Symmetrical Part (a Furnace Mandrel) Which Is Difficult to Spin Because of the Material and the Very Close Tolerances Desired. It consists of two parts, the chamber (upper) section and the tail cone, each of which was formed from a preformed truncated cone. Made of 20 CB stainless steel 0.115 in. thick, the part is a braze mandrel used to lay up individual tubes to form a thrust chamber. Entire rig is then placed in a furnace for brazing.

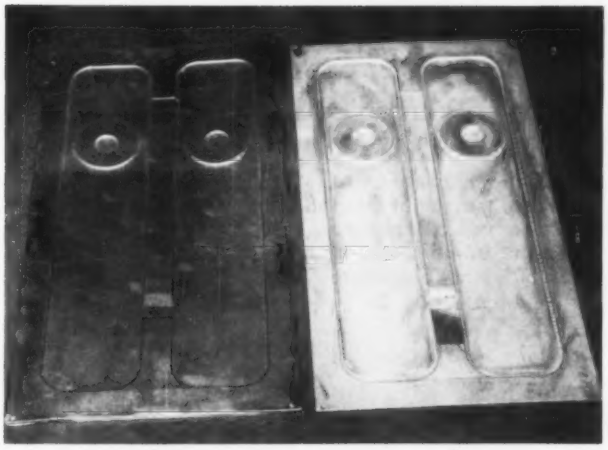


Recent Advancements in Thrust-Chamber Fabrication Make It Mandatory to Square the Ends of the Tubes to Very Small Corner Radii (Less Than 0.005 in.). Stainless steel tubes shown in this photograph were squared and punched in one operation. The ends were severed with a cut-off wheel and then squared, punched and trimmed simultaneously. Here, the explosive techniques not only result in a well-formed tube, but eliminate a troublesome punching operation as well. These holes are consistently the same and have no appreciable burr. Material is Type 347 stainless 0.010 in. thick and the tubes are ¼ in. square.

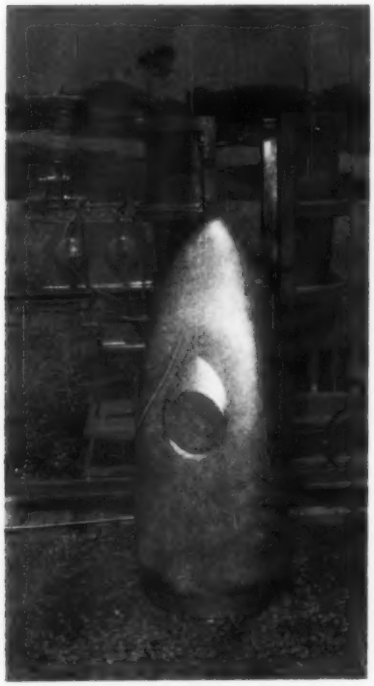
Although this Aluminum Hatch Cover Is Small (24 In. in Diameter), It Represents a Type of Forming Which Usually Requires Large Equipment. With the tremendous forces available in explosives, such operations are quite inexpensive and feasible. This part was made from 6061-T 6 flat stock 1½ in. thick.

The Outer Shell for a Rocket Motor Was Formed From Ordinary Piece of Seamless Stainless Steel Tubing (Type 321, 0.090 In. Thick). In one operation, explosive forming produces an unsymmetrical shape to a tolerance of ± 0.001 in. Part is about 8½ in. long.





Often in Making Thin-Walled Heat Treated Assemblies, Distortion Encountered During Quenching Requires That the Part Be Formed or at Least Sized After Punching. Ordinary jigs used to prevent distortion during heat treatment are often costly and inefficient. In this aluminum part, a pylon access door, explosive techniques have been utilized to complete the forming of the part in the solution-treated condition. Furthermore, the parts produced by this method are so uniform that they are interchangeable. The alloy is 6061-T 6 aluminum, 0.063 in. thick.



½-In. Diam. Type 321 Tube

0.005-In. Rolled Ta Sheet

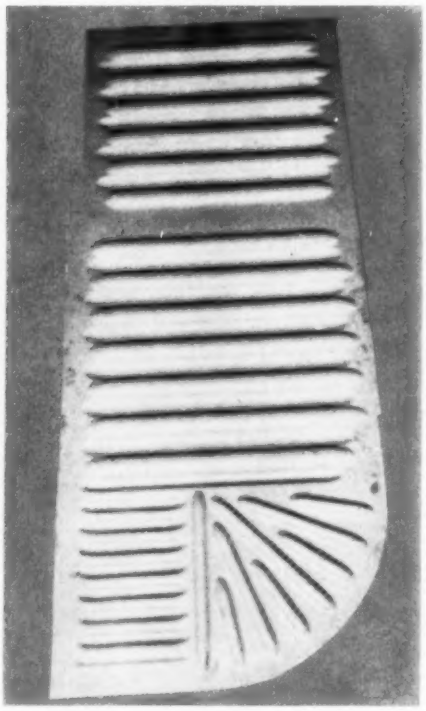
Tantalum Explosively Clad Within Stainless Tube

It Was Desired to Produce a Copper Part as Close to This Die Configuration as Possible. Explosive-formed part (left) duplicates the original except for material thickness.

Cladding Is a Relatively New Area of Application for Explosive Forming. As shown here, thin tantalum foil has been rolled into an overlapping cylinder and bonded to the stainless steel tube explosively. Bonds range from mechanical to metallurgical in nature depending on materials and techniques employed.

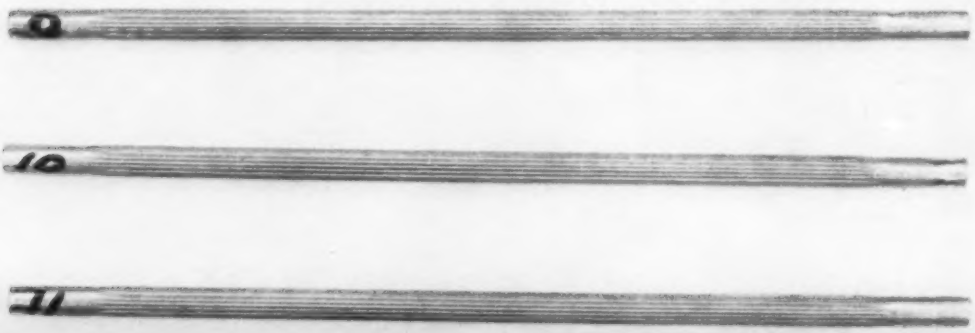
Many Times Explosive Forming Techniques Can Be Used to Produce Assemblies or Subassemblies by Forming a Number of Individual Details at the Same Time. This part, a water shield for a missile component, is a good example of a large detailed part produced rapidly in a one-shot forming operation. It is made of Type 321 stainless steel, 0.063 in. thick.

Often Explosive Forming Can Show Economic Advantage Over Conventional Techniques in Making Large Parts or Parts in Limited Numbers. In such instances, the single die required for explosive forming gives the process a cost advantage over the male and female dies usually required. Savings vary, but as a general rule, explosive forming is more economical for producing up to 60 parts such as the structural panel shown here, made of 0.050-in. Ph 15-7 Mo fully heat treated and aged after forming.



This 5-Ft. Diameter Hemisphere Illustrates the Potential of Explosive Forming in Fabricating Large Tank Components. The part shown contains welded sections which result in uniform wall thickness except at the welds. Very large parts must be made from welded blanks; a welded truncated cone requires only about 6% stretch during forming rather than a 50% stretch experienced by flat blanks.

These Heat Exchanger Tubes Must Present a Very Large Cooling Surface Within a Small Diameter. Each of the explosive-formed tubes (Type 347 stainless steel) contain internal and external longitudinal finning except at the ends which are smooth (for sealing). The steel is 0.015 in. thick.



High-Energy Forming

Ryan's Experience in Explosive Forming

*By FLOYD A. COX**

Experience at Ryan Aerospace has demonstrated that explosive forming can simplify fabrication of complex shapes and produce close-tolerance parts. Here are some examples of what can be done with the new technique which will point out its potential to design engineers dealing with tough forming problems. (G-general, NM-K34)

MANY DEVELOPMENT PROGRAMS have been conducted to evaluate explosive forming, and the results have provided data which permit design engineers to consider it as a useful production process. At Ryan Aeronautical Co., for example, we have produced 47 different types of shapes or configurations in numbers ranging from 25 to as high as 1000 parts. In both production and development, a total of 250 configurations have been formed.

Why Use Explosive Forming?

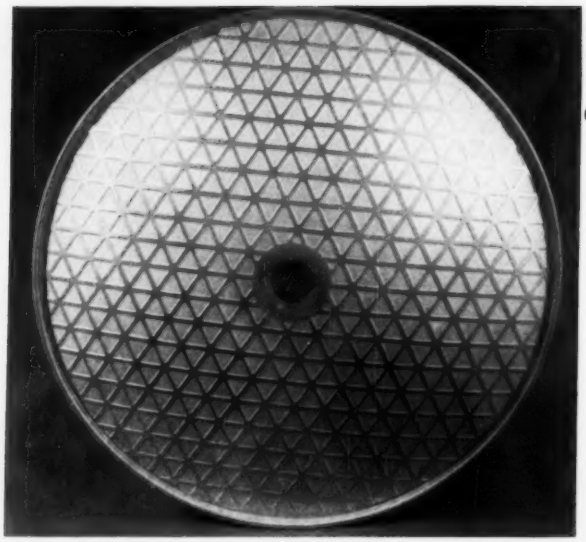
The success of explosive forming stems from these principle advantages:

- The size of explosively formed parts is not restricted by present facilities and equipment, but by other factors such as the size of dies and available sheet and the ability to handle the die and the material.
- Sufficient pressure and capacity for forming the strongest of our new superalloys is available through explosive forming.
- Explosive forming utilizes speeds up to hundreds of feet per second compared to conventional machines which form metals at speeds up to 5 ft. per sec. The use of high and low-pressure explosives can be varied to regulate the forming speed.
- Parts have been consistently produced to within 0.001 to 0.002 in. of the die because there is no spring back. Of the hundreds of dies made for this technique, not one has been machined to allow for spring back.
- On most explosive-formed configurations, thinning is no problem. When forming is severe, it can usually be accomplished by a combination of explosive forming and chemical milling.

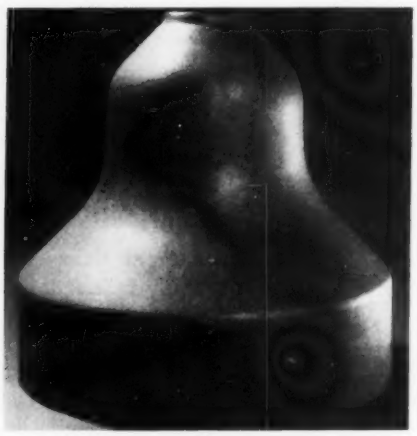
Where to Use Explosive Forming

Parts shown in the photographs on the next page illustrate the results of some of our work with explosive forming and demonstrate its usefulness. Generally we feel that design engineers will find this new technique particularly valuable for forming unusual bulges and shapes not readily formed by other means, for combining several parts into one piece, where a combination of explosive forming and heat treating would be required to get the desired yield strengths, and in making parts which would be impossible and impractical to form with a die and punch.

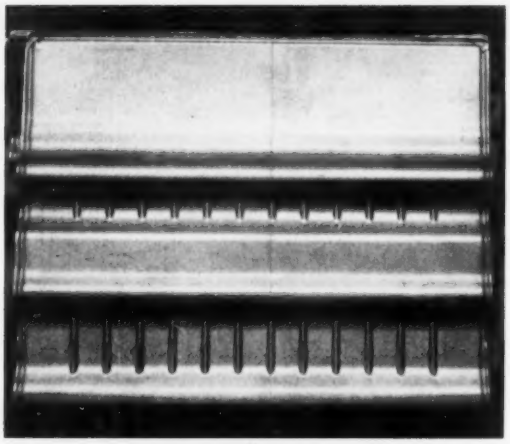
*Manager, Mfg. Research & Development, Ryan Aerospace, Div. of Ryan Aeronautical Co., San Diego, Calif.



Aluminum Reflector (24-In. Diameter) Before Final Trimming. Fabrication of the part combined explosive forming and chemical milling (note relief pattern on the back surface). Parts of this configuration require extremely close tolerances and unmarred surface finishes. Chemical milling, of course, lightens the part; it was done after forming.



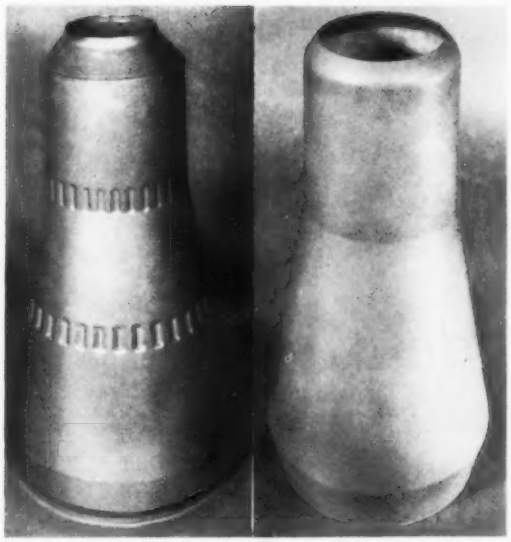
Bell-Shaped Sump of "K" Monel (0.040 In. Thick) for a Missile. The large diameter is 30 in., the small diameter is 5 in., and over-all height is 30 in. This part was originally fabricated from three pieces which were pressed, trimmed, welded together, and then sized. The final explosive-formed part was made from a rolled and welded cone and formed to the configuration as shown.



Engine Baffle Made of Hastelloy X, 0.093 In. Thick and About 5 Ft. Square. It was designed specifically for explosive forming and is produced in one piece to the size and contour tolerance required on the final assembly. The finished part was controlled within 0.006 in. of the desired contour.

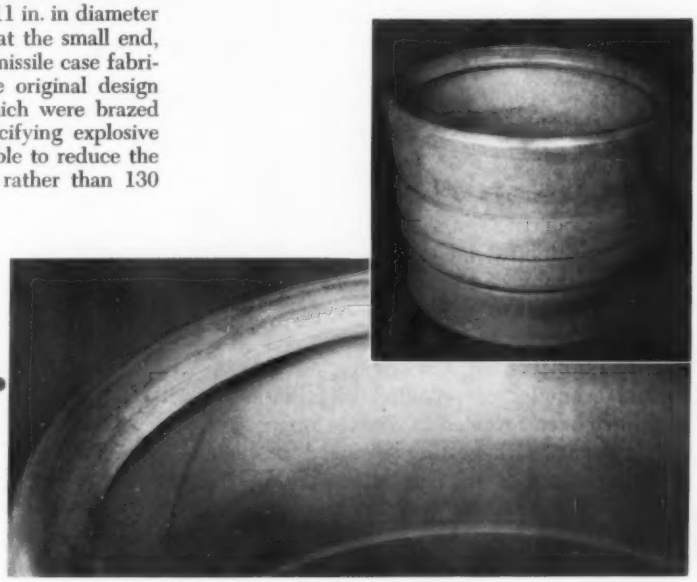
Explosive Forming Produced These Parts

View of the Back of an Aluminum Reflector Made by Explosive Forming. To add strength to the final assembly, the basic reflector is made with a front and back detail. The back, as shown, is fabricated with beads and mounting pads, and the front piece is made to the exact reflecting or radar quality required. After being formed, both pieces are joined either by bonding or spot welding.

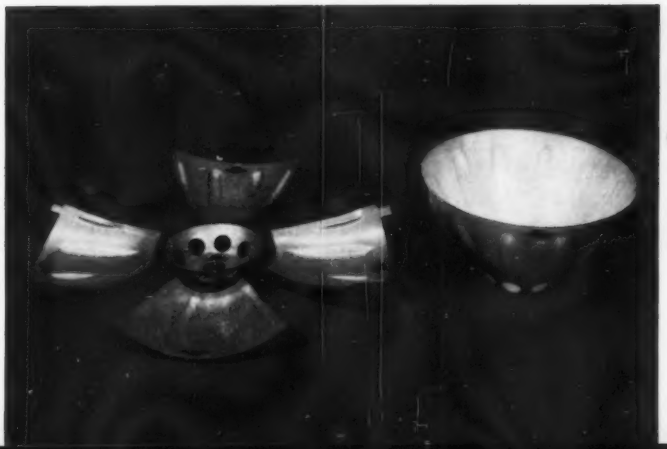


Outer Shroud of a Missile Component (Left) of Type 321 Stainless Steel 0.030 In. Thick. Shaped by explosive forming, it has 128 indentations formed into its surface. This part is about 11 in. in diameter at the large end, 6 in. in diameter at the small end, and 20 in. in length. It fits over a missile case fabricated from René 41 (right). The original design called for 128 separate spacers which were brazed between these two parts. By specifying explosive forming, the design engineer was able to reduce the assembly to a combination of two rather than 130 pieces.

Tailpipe of a Jet Engine Used to Power a Small Drone. Formerly made of three pieces welded together to obtain the elbow shape, it was redesigned as a one-piece rolled and welded cone which was then explosive formed to the shape shown (36 in. long, 10 in. diam.). Dimensional tolerance of the finished explosive-formed part in the bend area was held within 0.008 in. which was one third that of the original welded part.



Jet Engine Shroud Made of A-286 and Formed Within 0.005 In. on Contour and Within 0.008 In. on Diameter by Explosive Forming. The part is 0.063 in. thick and about 20 in. in diameter and is made as a one-piece welded cylinder. It was formerly made in two pieces and riveted around the top.



Inner Part of a Nose Cone for a Jet Engine. Measuring about 12 in. in diameter and 7 in. in depth, it was originally designed as an assembly of five parts (left). A configuration of this type can readily be made in one piece, as shown on the right, by explosive forming. The material is 0.030-in. thick 6061 aluminum and is formed in the annealed condition.

High-Energy Forming

Steel Parts Formed on High-Energy-Rate Machine

*By RALPH G. MONSEES**

High pressures applied at great speeds permit parts to be extruded or forged in one stroke to close tolerances and smooth surfaces. These characteristics open areas of application of high-energy machines to conventional metals such as resulfurized steels as well as those which are difficult to form. (G-general, F22; ST)

CAPABILITIES FOR MAKING PARTS in a high-energy machine extend to conventional metals as well as many of the so-called exotic materials. Being able to form a part in one dynamic stroke and then put it to immediate use with little or no machining has obvious advantages. Several examples of potential savings of this kind have been revealed in recent research and development work at the advanced products department of General Dynamics Corp.

Reduces Machining Costs

One of these involves the automobile part shown in Fig. 1. Fabricated from a billet of C 1146 resulfurized steel, it is ordinarily made as a rough forging, then machined to size. No standard forging technique has achieved the critical close tolerances required in the spline area. This part, however, has been forged in one stroke on a Dynapak machine (Fig. 2) to exact tolerance.

To forge it on the high-energy machine, the billet (2.35 in. diameter by 1.94 in.) was heated to 1950° F.; mold temperature at the start of forging was 400° F. Traveling through a stroke of 8½ in. and accelerated by a 900-psi. firing pressure, the ram exerted about 200 tons of forging pressure. Only the bearing surfaces required subsequent machining.

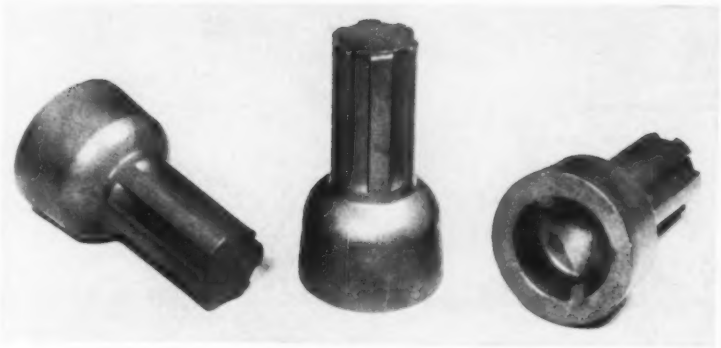
Accurate Gun Bolts Cold Formed

Another example of the potential for high-energy machines stems from a feasibility study conducted to find a more economical way of producing a gun bolt which required accuracy and a good surface finish. Using high-energy-rate forming, 100 parts of C 1118 steel (Fig. 3) were made, each within ±0.001 in. of the desired dimension in all directions and with a smoother finish than 63 rms. Lack of die wear indicated that a long run could be made from the same dies without any loss in accuracy.

To cold form the steel in one stroke, much consideration was given to the lubricant. In this instance, a commercial lubricant proved adequate and no trace of galling or die damage was evident. Billets were formed at room temperature and the die was kept under 400° F.

*Manager, Advanced Products Dept., General Dynamics Corp., San Diego, Calif.

Fig. 1 – Automobile Part of C 1146 Resulfurized Steel Was Forged in One Stroke in a High-Energy Machine. As-forged dimensions were accurate enough to eliminate the need for all machining except on bearing surfaces. The shaft stands almost 4 in. high



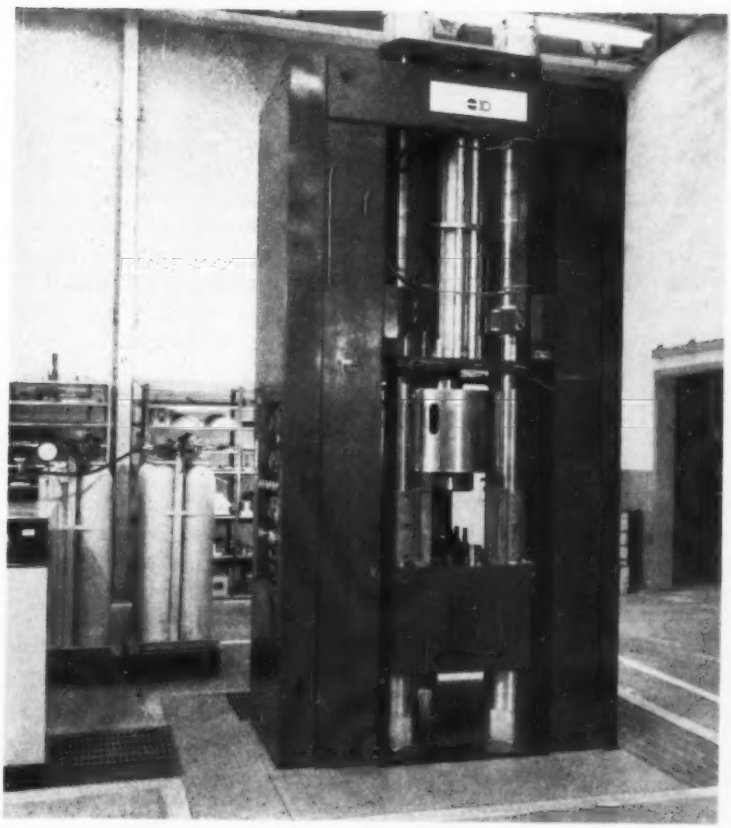
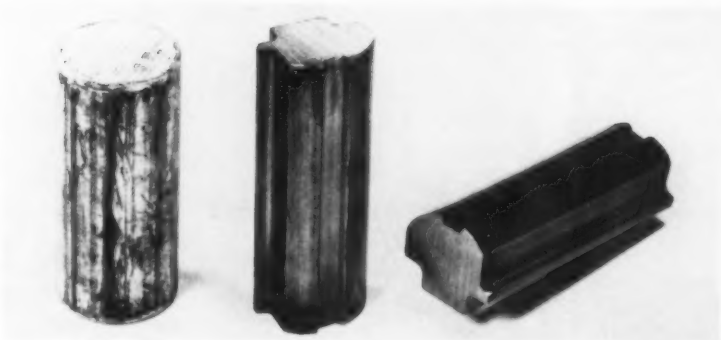


Fig. 2 – Vertical High-Energy Machine Built by Advanced Products Div. of General Dynamics Was Originally Designed for Forming Hard-to-Work Metals. Its ability to form parts which need little or no subsequent processing has extended its usefulness to conventional metals

Fig. 3 – Gun Bolt Slide Was Made in High-Energy Machine by Cold Forming. Part is C 1118 steel extruded from a 1¼-in. diameter by 2¾-in. billet (left). In as-forged condition it has a dimensional accuracy within ±0.001 in. and a surface finish better than 63 rms.



High-Energy Forming

Explosive Forming With Combustible Gas Mixtures

*By JOHN MILLER and PHILIP KRUSE**

Working with mixtures of hydrogen, oxygen and an inert gas, Boeing engineers are experimenting with a forming method which possesses the advantages of conventional explosive forming but eliminates some of its limitations. Forming pressures can be controlled more accurately and the combustible gas is, in effect, an ideally shaped charge since it is always in contact with the workpiece. (G-general, NM-k34)

IN FORMING WITH EXPLOSIVE GAS MIXTURES, the detonating type of explosive charge is replaced with a mixture of combustible gas and oxygen. The die is completely sealed, the combustible mixture is then fired, and the part is formed by the resulting pressure build-up.

Work on this method of forming began at Boeing Airplane Co. early in 1960; it is aimed at overcoming some of the limitations of conventional explosive forming in which solid explosives are used. For example, some materials and shapes, particularly in the thin gages, present a forming problem when detonating types of explosives are employed. Part fracture can occur unless forming is done with a small amount of explosive, or unless the explosive charge is moved away from the workpiece. Conversely, if the amount of the explosive is too small, it may not fire, and if the charge is too far away, it is difficult to obtain uniform forming pressures. A technique is required which provides lower forming rates and pressures that can be better controlled than high explosives; it must, however, retain the advantage of rapid forming rates. The use of combustible gas mixtures appears to be a solution to the problem because the forming rates which result are still high compared to those encountered in conventional forming but are less than those produced by detonating explosives.

*Mr. Miller is lead engineer of the explosive forming group and Mr. Kruse is lead engineer of the advanced projects group of the Boeing Co., Seattle, Wash.

Advantages of Explosive Gases

Combustible gas mixtures have several apparent advantages. For one thing, the gas fills the cavity and provides intimate contact with the workpiece. This is an ideal shape for a charge. The die chamber can be quickly recharged and fired. In addition to slower burning rates than obtained from detonating-type explosives, gas mixtures give more uniform forming pressures. The pressure peak is sustained longer and a much wider range of pressure control is feasible. Gas volume, the mixture ratio, and the initial pressure can be easily controlled, and the combination of Boyle's and Gay-Lussac's or Charles' law ($PV/T = P'V'/T'$)

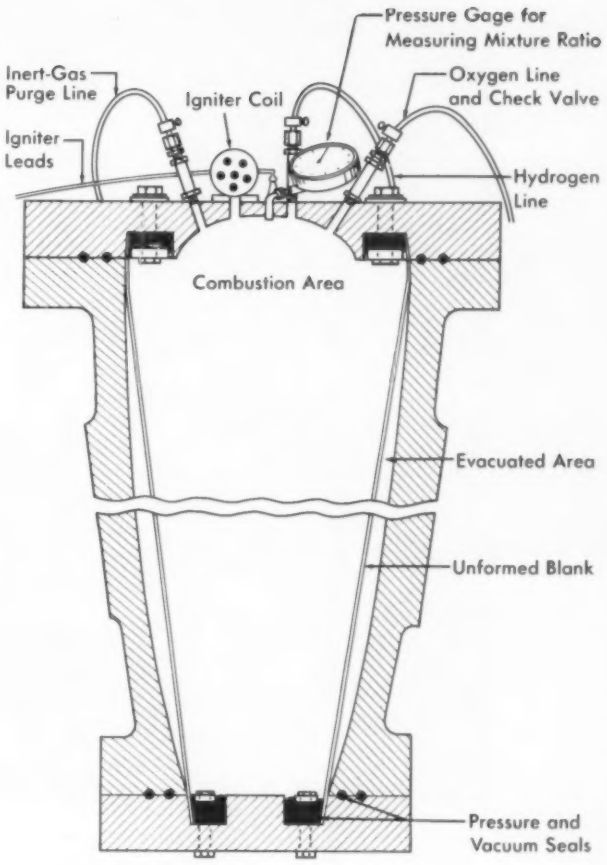


Fig. 1 – Cross Section of Typical Die for Forming With Combustible Gas Mixtures. Use of gaseous rather than solid explosive gives better control of forming pressure

provides a simple theoretical means for relating the important factors. In the system we have chosen for development, the gas volume, the initial pressure and ratio of gases can be varied. A mixture of hydrogen, oxygen and an inert gas serves as the explosive. In this combination the products of combustion are the simplest – water and excess gases.

Experiments at Boeing

At Boeing, combustible gas mixtures have been employed for both sizing and forming operations. Charge volumes ranging from ¼ to 70 cu.ft. and starting pressures from 1 atmosphere to 14 atmospheres have been used. Initially, the effects of mixture ratio and pressures were investigated by free forming 10-in. diameter domes in a standard die. Later, dies previously used for high-explosive forming by the submerged process were adapted for use with combustible gas mixtures. Figure 1 and 2 show the important details of the equipment. Materials ranging from soft aluminum (Fig. 3) to high-strength alloys (Fig. 4) have been successfully formed.

Fig. 2 – Details of Die Shown Here are Similar to Those Presented in Fig. 1. Combustion area is smaller because this die is used for forming domes rather than cylindrical shapes. Size of equipment and the fine process control which can be exercised may mean that the forming operations can be performed safely in the plant

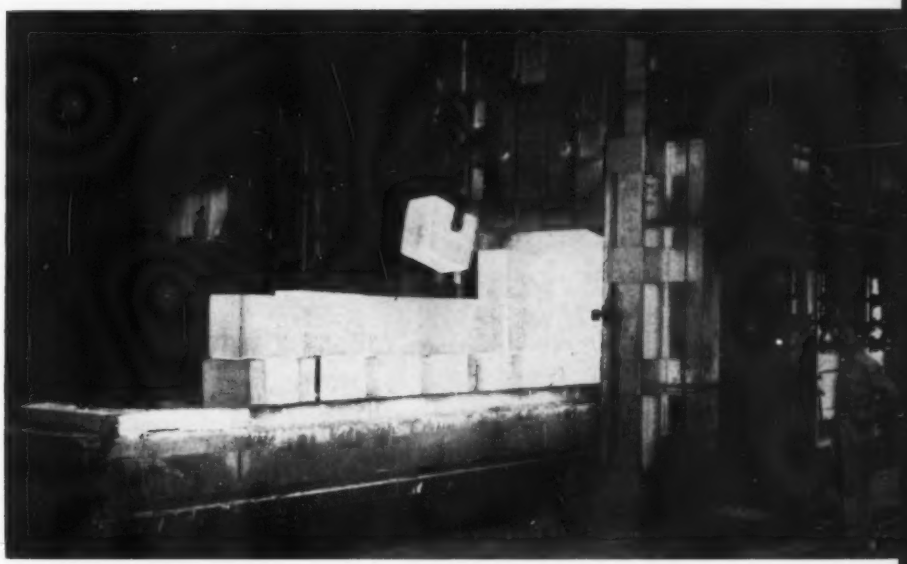
Fig. 3 – Shape of This Part of 0.063-In. Thick 3003-0 Aluminum Is Suitable for Forming by Gas Mixtures

Hydrogen-Rich Mixtures Used

In our present procedure we place the workpiece in the die and draw a vacuum between them. The volume to be occupied by the charge is then purged with an inert gas before introducing hydrogen and oxygen. Although many mixture ratios are being presently tested, they have been consistently hydrogen-rich to minimize oxidation. In some instances, an inert gas has been mixed with the hydrogen and oxygen to dampen the charge and further refine our control of pressure. Two methods are currently being used to fire the charge – an electric spark or a glow plug. It now appears feasible that forming operations can be moved indoors and performed above ground. This compares with forming with high explosives which must be done at remote areas in a water pit.

Fig. 4 – Cylindrical Shape of Hastelloy N-155 (0.050 In. thick) Was Formed to Within ±0.005 In. Using Exploding Gas Mixtures as The Forming Medium

Only 3½ Hr. in the Furnace Sufficed to Heat This Load of Die Blocks (Weighing 23,832 Lb.) to 1575°F. for Quenching. Time required by conventional methods usually is a minimum period of 20 hr.



Computer Helps Speed Heat Cycles

*By C. L. FENG**

An analog simulator, termed "Thermolog", has proved useful in obtaining hard-to-get information necessary for designing and evaluating thermal systems. Specialized heat problems can be solved in a few hours after set up of the simulator circuitry. (J2, 18-74, W23k, W24n)

BECAUSE THE HEATING of die blocks and other heavy sections of similar nature has long been considered such a time-consuming operation, much attention has been directed at devising procedures for heating them more rapidly. One new tool which is proving useful for predicting the effects of rapid heating is the "Thermolog", an analog computer, shown in Fig. 1. Designed and used by our engineers to solve heating problems, this unit can be set up so that electrical parameters act as stand-ins for analogous thermal entities in an electrical "model" of the object under examination. In it, network circuitry duplicates electrically the variations in thermal conditions of the object as it is subjected to changes in temperature and time. As an added feature, "time" can be stopped during a simulation; this allows simultaneous readings to be made at as many points in the "heated" object as desired, within the capacity of the simulator. Changes in conditions within the thermal equation can also be applied, and "heating" can then be resumed until it is desirable to stop time again for further readings. Thermal responses that would actually take place in a heated object are matched in the network with electrical parallels as follows:

THERMAL RESPONSE	ELECTRICAL ANALOG
Temperature	Voltage
Heat flow	Current
Thermal conductivity, or surface heat transfer coefficient	Resistance
Heat capacity	Capacitance

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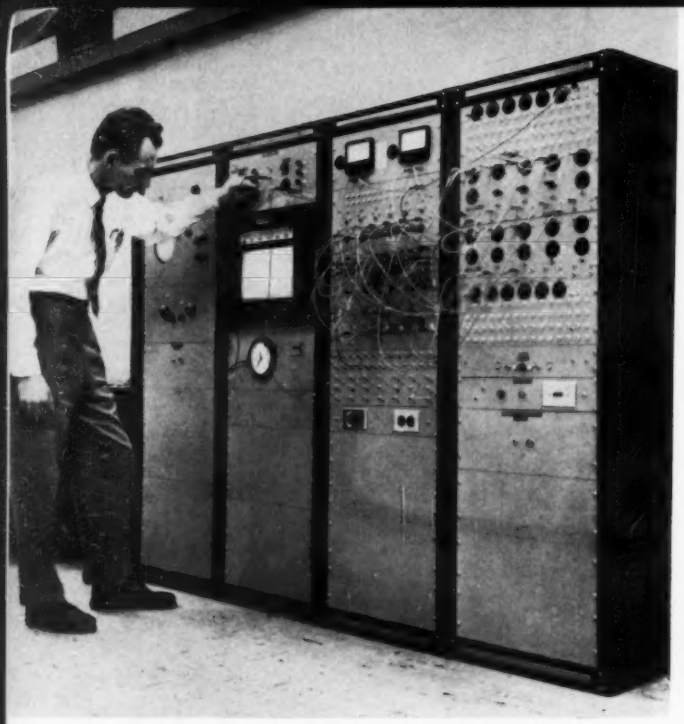


Fig. 1 – Through the "Thermolog", an Analog Simulator, Engineers Can Foretell the Results of Heat Processing Problems. In this unit, electrical quantities, such as voltage and current, substitute for thermal quantities, such as temperature and heat flow

Applying the Simulator

A die-block heating cycle, conventionally 20 to 30 hr., has been considered critical because steel die blocks have been regarded as inherently crack-sensitive. However, investigations with the aid of this computer showed that heating cycles for die blocks could be reduced to 3 to 4 hr. This has been verified by plant experience. Obviously, the faster heating rates associated with these shorter cycles result in considerable savings in fuel.

To begin this study, we first constructed an electrical model of a representative die block 36 by 22 by 22 in., adjusting the circuitry so that the "block" would be "heated" from 1200 to 1575° F. at the center. Temperature at its surface was not to exceed 1650° F. at any time. In this particular furnace, which was designed to be loaded at one end and unloaded (into a quench) at the other, radiant burners, located close to the work and spaced at strategic points in the furnace walls, beam heat at high thermal gradients directly upon the work. Thus, heat transfer from the wall is minimized. (However, it is a factor to be considered at the beginning of the cycle utilizing a hot furnace.)

We first investigated the cooling of the refractory walls (of the furnace) that occurs when the furnace charge door is opened for loading, or the discharge door is opened for unloading into the quench. Assuming loading or unloading time to be 1 min. and the furnace wall to be at approximately 1685° F. before the door opened, we found that the temperature of the refractory dropped to 1425, 1530 and 1540° F. at depths of 0.45, 0.90, 1.35 in., according to the simulator. These effects are illustrated by Fig. 2, which also shows the heat recovery after the door is closed. The entire wall attained a steady gradient within an hour.

Phase two of the simulation treated the internal and surface temperatures of the die block during heating. For the calculation, the block

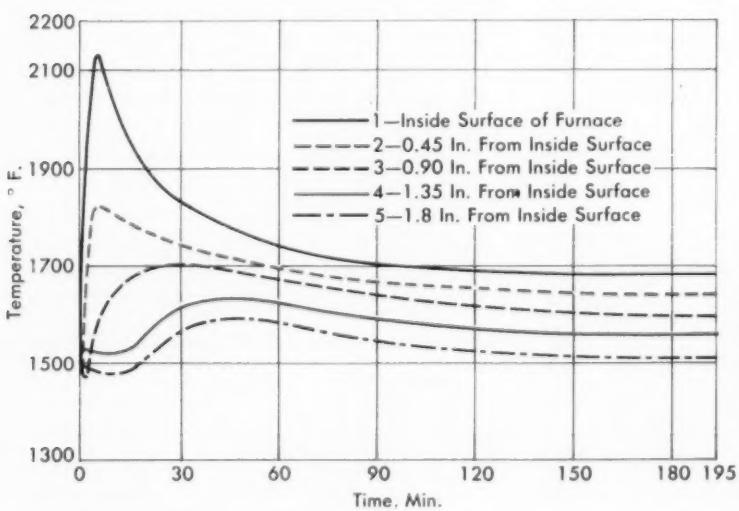


Fig. 2 – Furnace Wall Temperature During Die-Block Heating Cycle, Starting at 1685° F. Surface Temperature (Before Opening Door). When the door is opened for 1 min., the temperature drops. However, recovery is rapid when the door is closed. These curves were developed by the simulator

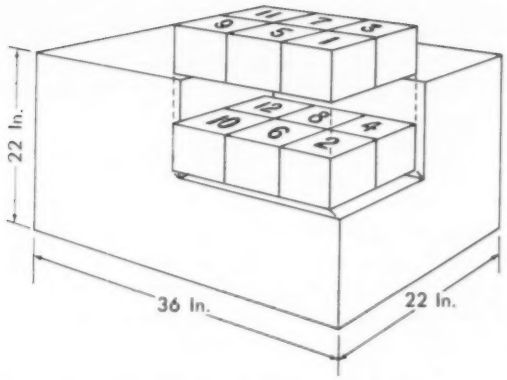


Fig. 3 – For the Simulator Study, the Die Block Was Divided Electronically Into Elemental Blocks. Heating curves were then developed for each block

was divided into sections as shown in Fig. 3. As one would expect, the simulator showed that the corner block, No. 1, having three faces exposed to furnace heat, required the shortest time to heat to 1575° F. Next in length of time required for heat up came the sections exposed on two sides, namely, blocks No. 2, 3, 5, and 9. Curves for those blocks which presented only one face to the direct heating (No. 4, 6, 7, 10, 11) showed that their heating rates were slower than those for blocks with two or more faces exposed. Inside blocks, No. 8 and 12, which must be heated by conduction, required the longest heating time. Block No. 12, representing the innermost portion, reached a temperature of 1575° F. from 1200° F. in 195 min.

The third study phase determined the heat input to the furnace and the work, and indicated useful heat for the cycle duration. To insure a practical turndown ratio (ratio of maximum-to-minimum Btu. input within which the burner, or burners, will operate properly), the maximum input selected was ten times the minimum Btu. The Btu. input curve, which is shown in Fig. 4, indicates that the maximum input of 1.08×10^6 Btu. was applied for only 2 or 3 min., dropping sharply to a fraction of this amount in 15 min.

Using the Computer's Findings

Plant experience verified the findings by showing that the heating cycle for hardening die blocks could be lowered from 30 hr. to 3 or 4 hr. In fact, one die-block manufacturer has successfully reduced heating cycles on loads up to 20 tons by loading the die blocks into the furnace at room temperature, lighting the furnace, and immediately heating at the highest possible rate (Fig. 5) to the desired temperature for quenching. In this operation, the maximum charge, which can be made up of blocks of several sizes, measures up to 20 by 3 by 2 ft. The blocks are heated between the two furnace walls by gas burners which are spaced to produce an even distribution of heat to all the pieces in the load.

Other Areas of Application

Simulation of fast heating by analog has been found accurate in other interesting applications, one of which is in the heating of steel

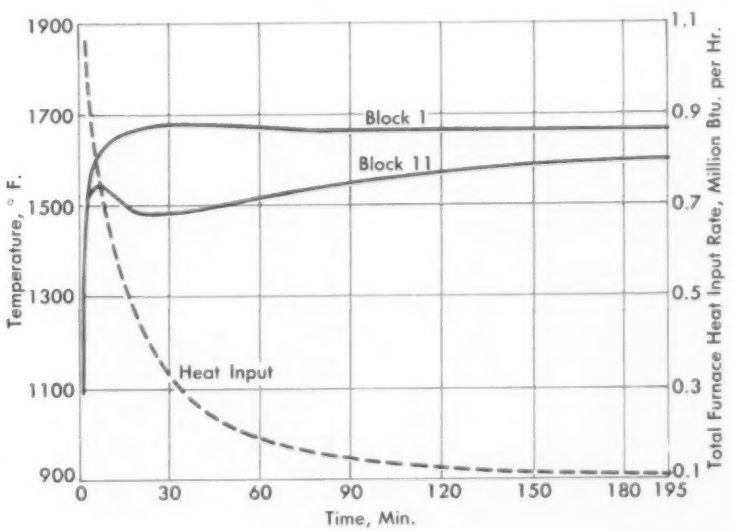


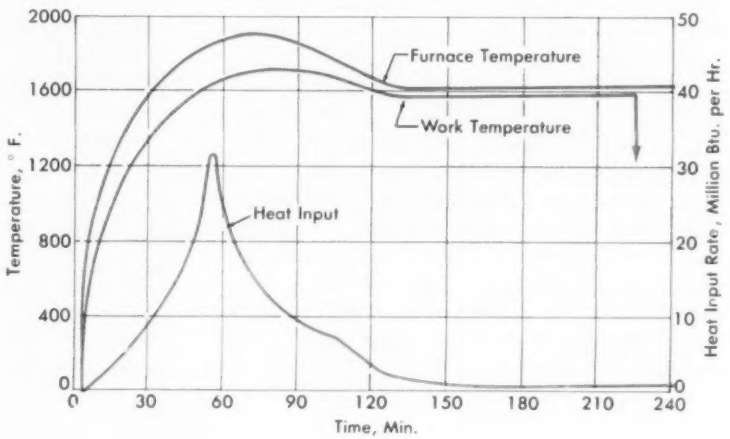
Fig. 4 – Hourly Btu. Input to Furnace, and Resulting Surface Temperatures of a Corner Elemental Block (No. 1) and One Outside-Center Elemental Block (No. 11). Note that rapid heating is only needed for a short time

rolls for hardening. The forged roll in this simulation is 14 in. in diameter, 32 in. in length, and has an internal bore 2½ in. in diameter. Estimated weight is 2240 lb. In heat treating this roll, it is necessary to heat the entire roll face and cross section to about 1550° F., carefully controlling the temperature so that heating will be uniform throughout. Conventional practice would require several stages of heating over a period totaling 18 hr. When analog simulation indicated that it would be possible to reduce this cycle to one tenth of this time, this was tried.

Heating curves for an experimental roll under actual heating conditions are given in Fig. 6. It is interesting to note that the roll surface attained the desired temperature of 1550° F. in 20 min. and was held at this point. The internal bore temperature reached 1250° F. in 38 min., and the desired temperature distribution throughout the roll (1550° F. outside, 1520° F. in the bore) was reached in only 95 min. — in contrast to the 20 hr. required by conventional practice.

Current simulation studies in heating large rolls (up to 54 in. diameter) and other parts of similar size indicate that drastic reductions in cycle times will often be possible. At this time, data for actual heating of large rolls are incomplete; however, indications are that conventional practice of heating over a long period such as 60 hr. may be replaced by cycles as short as 8 hr. This computer has also been successful in problems such as determining the time needed to melt aluminum pigs in a molten bath of aluminum, calculating the heat input curve for a rocket nozzle, and ascertaining the heat losses and cooling times for glass bottles. In the future, this device will undoubtedly be used for many other applications.

Fig. 5 — Heat Input and Work-Load Temperatures During 3½ Hr. Heat-and-Soak Cycle for Die Blocks Shown on p. 79



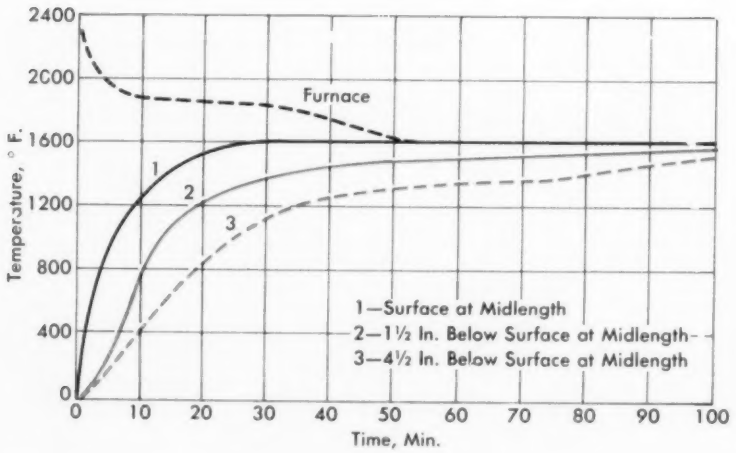


Fig. 6 — Actual Temperature Curves for Three Points in a Mill Roll. This roll was heated to hardening temperature in one tenth the time conventionally allowed

Factors to Consider in Selecting Ultrasonic Testing Equipment

*By R. A. SEIDEL**

In choosing an ultrasonic instrument for flaw detection, an engineer must know the type of service it is to perform. Ruggedness, degree of accuracy needed, ambient illumination conditions, instrument stability, dependability, simplicity of operation, size, weight, and portability are all important factors to consider. (S13g, 1-53)

THOUGH THERE ARE SEVERAL different types of ultrasonic flaw-detection methods (resonance techniques, continuous-wave tests, frequency-modulation systems, and pulse-echo techniques), this discussion is limited to the most frequently used – the pulse-echo technique. Instruments employing this system are used chiefly for detecting flaws in metal parts and structures, although they are also applied to determining dimensions of hard-to-measure parts such as large, complex forgings.

Before discussing the criteria for instrument selection, it would be well to describe the operation of the various circuits of an instrument employing the pulse-echo system. Figure 1 shows a block diagram of a typical pulse-echo flaw detector. The power supply, which furnishes the various voltages needed to operate the different circuits, is fed by commercial alternating current – usually a 115-v., 60-cycles per sec. source. This section consists of high and low-voltage circuits – the high voltage supplies plate and deflection voltages, while the low

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Laboratory Technician Applies Finishing Touches to the Flat-Bottomed Target Hole in One of a Set of Aluminum Reference Blocks for Ultrasonic Testing

voltage supplies filament power to the tubes. The synchronizer, or "clock" as it is sometimes called, acts to coordinate the instrument timing to produce a specific sequence of operations in the rest of the circuits. It furnishes starting signals to the pulser, horizontal sweep, and marker generator. The pulse generator is the source of the short, high-frequency, repetitive electrical pulses that are sent to the search units and amplifier circuits, and the search unit serves as a transducer or energy converter. When the latter receives electrical pulses sent out by the pulse generator, it transforms them (through piezoelectric action) into mechanical vibrations of ultrasonic frequencies which then enter the material being tested. Some of these vibrations are reflected back to the transducer, which then acts in a reverse manner, converting the mechanical vibrations to electrical pulses. These electrical signals then go to the echo amplifier, a very powerful unit, which amplifies the signals of both the outgoing pulses from the pulse generator and the incoming pulses from the search unit.

To produce the cathode-ray picture, the pulse signals leaving the amplifier are applied to the vertical deflection plates of the cathode-ray tube. These signals cause the beam to trace out vertical indications representing the amplitude of received signals. In the meantime, the beam, energized by the sweep generator, sweeps horizontally along a time base (sweep line) which represents test depth. The marker generator applies a series of symmetrical waveforms to the vertical deflection plates of the cathode-ray tube. These are used as a measuring scale to determine the distance between transmitted and reflected indications on the viewing screen.

Criteria for Selecting Instrumentation

In general, several features must be considered in any instrument for pulse-echo ultrasonic testing. These are as follows:

1. Ruggedness – Many tests are performed in areas in which equipment may be subjected to considerable abuse or may be roughly handled in transport from one job to another.

2. Degree of accuracy – Accuracy requirements depend upon whether measurements may be qualitative (set up on a "go-no go" basis), or must be quantitative (where exact signal amplitudes must be measured). Different types of sonic test equipment offer varying degrees of accuracy, resulting from differences in circuit design and variations in the quality and type of presentation.

3. Ambient illumination conditions – The type of lighting conditions under which the instrument is to be used must be considered. Some instruments have much brighter or high-contrast presentations, and consequently provide better images for viewing than others.

4. Instrument stability and dependability – Certain types of instruments are more reliable than others from the standpoint of changes in operating characteristics. One important consideration is the amount and type of maintenance required to keep an instrument in good operating condition, as well as the field service provided by the factory for repair work.

5. Simplicity of operation – Certain applications require the use of a relatively uncomplicated instrument equipped with a minimum number of controls and adjustments for relatively unskilled operators.

6. Size, weight, and portability – Ease of handling is important where an instrument may be used in various operations or localities.

Some of these factors are relatively easy to evaluate or estimate by discussion with vendors; others require experience based on usage. The following considerations are based on both sources of information.

Cathode-Ray Beam Intensity and Focus

Though it should be evident that dim or fuzzy signal traces are undesirable, their detrimental effect cannot be overemphasized. When operating properly, all instruments should have a sharp and clear presentation. Unfortunately, some images have relatively poor contrast and brightness. This can be an exceedingly trying problem, especially when testing must be performed in brightly lighted areas.

Units are now coming out with special controls for improving the brightness and contrast which makes possible not only increased brilliance but faster scanning speeds in automatic tests. It might be added that any instrument that is intended for more than one application should be equipped with external intensity and focus controls. Thus, the operator is given maximum latitude in his selection of trace characteristics. It has been found that much operator fatigue and resulting test inaccuracies can be reduced or eliminated by giving proper consideration to this instrument characteristic.

Such features as illuminated screen grids often greatly enhance the versatility of instru-

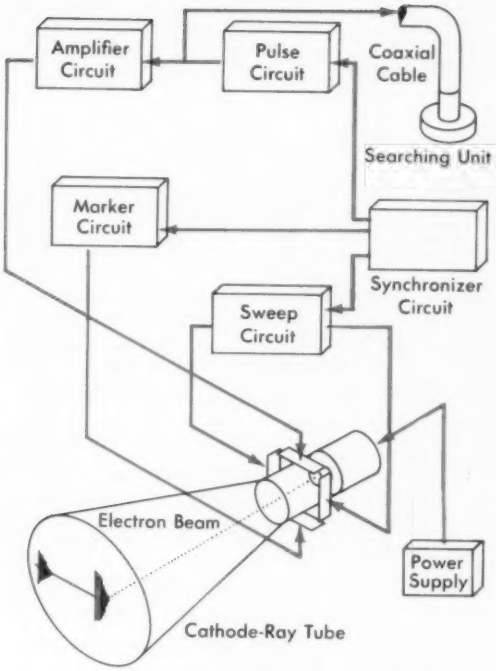

Fig. 1 – Block Diagram of Ultrasonic Flaw-Detection Instrument Employing the Pulse-Echo Technique. Operation of each component is described in the text

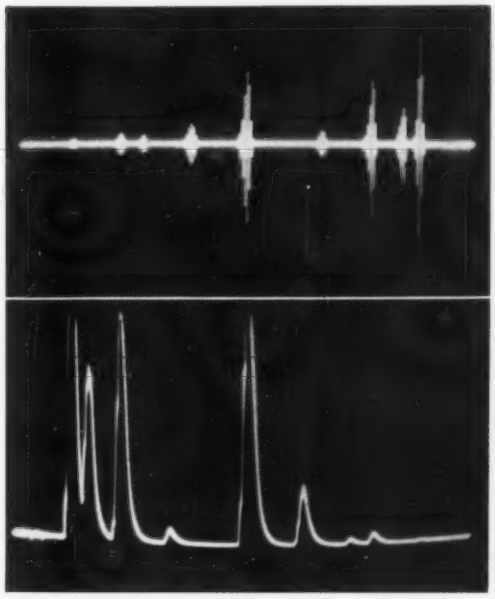

Fig. 2 – RF and Video Signal Traces. The RF trace, shown at top, is symmetrical about the X-axis; it provides good resolution. The video presentation, though it appears clearer than the other, is considered to provide less definition

mentation, especially when oscillograms or photographic records are needed. Photographs of screen displays on such instruments provide a permanent calibration scale from which signal amplitudes can be measured directly from the picture. Further, such grids help to reduce viewing fatigue.

Portability – an Important Factor

Electronic instruments which are highly accurate, extremely rugged and reliable, and easy to service because of adequate component spacing are usually complex and somewhat cumbersome. Such is certainly the situation with ultrasonic test instrumentation. One typical unit, for example, has a copper-clad case of heavy steel. Though extremely rugged, this instrument weighs almost 100 lb.; it certainly cannot be considered a portable instrument suitable for one man to carry around the shop. However, experience has shown that this unit can withstand the brutal mistreatment to which delicate equipment is sometimes subjected during commercial transit or in regular use in shop areas.

Another ultrasonic unit which does essentially the same job is quite small, uses transistorized circuitry, and is extremely compact. Since it weighs less than 40 lb., it can be readily carried by one man with a minimum amount of effort. With reasonable care, it might even be carried aboard an airplane as part of the luggage. However, since its cabinet is relatively thin and fragile, it cannot be considered a rugged piece of ultrasonic equipment.

Other examples of variations between individual pulse-echo units could be cited, but there would be little point to it. In general, it may be said that the heavier an ultrasonic unit is, the more versatile (from the standpoint of additional adjustments) and substantial it is. Of course, portability is sacrificed. Such instruments are usually best suited for laboratory or semipermanent installations.

Two Types of Signals

If one were to view indications on cathode-ray screens of various instruments simultaneously and side by side, perhaps the most striking difference would be in the type of trace presented on each screen. The most commonly used presentations are the so-called video and RF traces. As Fig. 2 shows, they are quite

different. The RF presentation, for example, exhibits signals both above and below the sweep line. This type of presentation provides maximum resolution for locating defects close to the surface or for separating signals following closely upon one another.

Since this presentation is symmetrical about the X-axis, it might be argued that almost half the cathode-ray tube screen area is wasted because the information presented below the line is a mirror image of what is above. Thus, the maximum viewing area is not fully used, and what is known as the total dynamic range of an instrument may not be completely realized.

Figure 2, bottom, shows a typical video presentation. It should be pointed out that this type, though cleaner and less-cluttered in appearance than the other, inherently provides far less signal resolution because of its broader pulse characteristics. It is, in fact, merely an RF presentation with the bottom half electronically clipped off, and presented such that only the outline of the original pulses, added on to the top half, is shown. Thus, larger signals are indicated, but flaw definition is more limited. In spite of this, the video trace seems to be gaining in popularity because it appears much easier to read.

Range Markers

To provide a means of measuring the depth of a flaw indication, a series of symmetrically shaped waves is electronically superimposed on, or beneath, the regular sweep line of the test presentation. The lengths of these waves can be adjusted to represent inches or feet of the material being tested. Figure 3 shows three of the most commonly used types of markers in ultrasonic instrumentation today. The square-wave markers shown at the top are easy to distinguish from the spike-like echo signals. They generally provide the most precise means of measuring flaw depth. Figure 3, center, shows pyramidal markers. This shape has been shown to be especially useful in an angle-beam test where the sonic energy is sent into a piece at a 45° angle, bouncing back and forth between the walls (of a pipe, for example) as it travels on through the part under test. These markers are designed to simulate the actual path of the search beam passing through the piece, thus making it easier to determine flaw depth with respect to the outside diameter and inside diameter (or top and bottom surfaces) of the test piece. Figure 3, bottom, illustrates a third type of marker wave. Instead of having equal positive and negative values, as do the other two styles, it is simply a compressed negative wave – the result is a type of sharp spike which resembles the graduations on a rule. Used with the video presentation, these markers are easily distinguished from echo signals since they deflect in opposite directions.

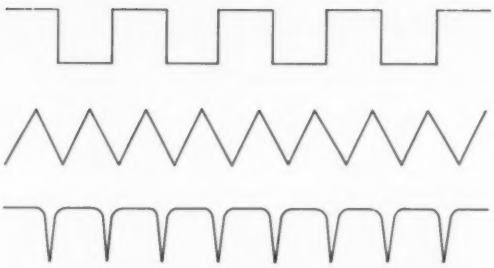

Fig. 3 – Types of Marker Systems. Symmetrical wave forms are superimposed on the screen in such a manner that the operator can measure depth of an indication. The diagonal wave form is particularly useful in angle-beam tests

Various Screen Sizes

Most instruments employ a 5-in. cathode-ray tube, though there are exceptions. One new unit, for example, has a 12-in. tube; others have had 7-in. and 3-in. tubes. It might seem that the larger the screen the better the presentation. However, just as in television, large tubes usually are undesirable for close viewing. Moreover, they generally result in more expensive and bulkier equipment. There is usually no need for providing a signal larger than that which can be presented by a 5-in. tube, except in some automated techniques where the scanning transducer must be positioned some distance from the viewing screen of the test instrument. In addition, it might be kept in mind that larger screens do not necessarily provide any more picture information. In fact, their presentations may have much lower contrast and definition than those produced in smaller tubes.

Operational Characteristics

One of the most important factors to consider in choosing pulse-echo equipment is the limit of vertical linearity of the instrument. Since the amplitude of the displayed signal is, in general, directly proportional to the reflecting area of the defect which causes it, accurate amplitude measurements are quite useful for

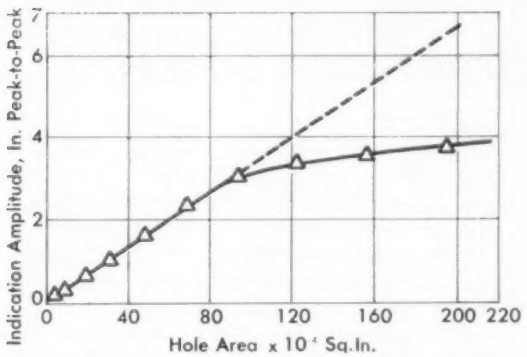

Fig. 4 – Graph Illustrating Range of Vertical-Deflection Linearity and Dynamic Range. Up to Block No. 7 (Alcoa Series "A" test blocks), the amplitude of the signal displayed on the screen is directly proportional to the area of the defect. Since the curve begins to drop off at about 2¾ in., this particular instrument is described as having a vertical linearity limit of 2¾ in. peak-to-peak

determining the size of the actual flaw. The range of vertical-deflection linearity of a test instrument might be most conveniently described as being that vertical screen limit (measured in inches from the sweep line) over which the instrument is capable of presenting the amplitude of indication heights in correct proportions equivalent to their respective received-signal strengths. As an example, Fig. 4 is a typical plot of indication amplitude as a function of flaw area. For these particular tests, the flaw targets were flat-bottomed holes contained in a set of Alcoa ultrasonic reference standards (see photo, p. 83). This particular set consisted of ten aluminum blocks (instead of the usual eight), each 2 in. square, and 3.75 in. long. All of them contained a flat-bottomed hole drilled into the base, with hole diameters varying in 1/64-in. steps, from 1/64 to 10/64 in. diameters.

Using a constant instrument gain setting, a responsive curve, based on measurements taken with these or similar blocks (the target areas of which are known), can effectively indicate the limit of vertical linearity of the test instrument.

The instrument represented in Fig. 4 could be described as having a vertical linearity limit of about 2¾ in. peak-to-peak. Therefore, any defects as large or larger than those found in the No. 7 block (at this gain setting) would not be shown in their true perspective and their reflecting areas would probably be miscalculated. Amplitude measurements on such an oscilloscope are necessarily limited to 2¾-in. values, restricting the applications of this instrument for quantitative, flaw-evaluating purposes. When choosing an instrument to be used for recording precise quantitative data, the engineer should particularly consider that instrument offering the highest vertical-deflection linearity.

Dynamic Range

Another important characteristic is the instrument's dynamic range, the ratio of maximum to minimum sizes of flaw indications that can be adequately distinguished on a test instrument screen at a constant gain setting. According to tentative A.S.T.M. specifications, the dynamic range of an ultrasonic test instrument is defined in ratio form by determining the largest hole in a series of test blocks that will provide an indication amplitude at least 10% greater than the next smaller hole size. The square of that block number (which defines its relative reflecting area-ratio) numerically indicates the limit of the instrument's dynamic range. Thus, when using the Alcoa Series "A" blocks, a dynamic range of 64 to 1 can be achieved if an instrument is capable of distinguishing between the amplitudes of No. 7 and No. 8 blocks with the No. 8 block indicating at least 10% larger than No. 7 on the screen at the gain setting which permits a No. 1 block also to be discernible. (For example, the dynamic range of the instrument of Fig. 4 terminates at the No. 8 block – 64:1.) The importance of this characteristic lies in the fact that an instrument having a very small dynamic range is severely limited in its ability to present various signals over a reasonable amplitude range. Consequently, frequent gain control adjustments or extrapolating procedures might be necessary to determine whether one defect was larger than another. A dynamic range of about 50 to 1 is generally considered to be adequate for most testing applications.

From the foregoing, it can be seen that considerable variations in design philosophy exist among the manufacturers of ultrasonic testing equipment. Such differences affect the versatility, durability, simplicity of operation and cost as well as many of the important operating characteristics of such equipment. Therefore, in choosing any instrument for a specific application, it may be necessary to compromise and select that instrument most closely suited to one's individual needs.

*Nucleonics in Testing and Process Control**

ENGINEERS, RESEARCH DIRECTORS, and management should be aware not only of the widespread utility of radio-isotopes in nondestructive testing, but of the many other applications for nucleonics which increase efficiency and productivity of existing operations. A wide range of radio-isotopes which emit four types of radiation – gamma, beta, secondary x-rays and neutrons – are now being produced in reactors. This variety of penetrating, nondestructive radiation provides convenience, differentiation, and response for many control and inspection operations.

Gamma Radiation – Gamma-ray radiography – using cobalt 60, cesium 137, and iridium 192 – possesses special characteristics which make the method particularly useful for inspecting medium-to-thick sections of materials. Today many industries have found they must employ radiographic inspection on a rather large scale; for example, during installation of large-diameter pipe, it is accepted practice to radiograph every weld in pipelines hundreds of miles long. Up to 10,000 welds may be radiographically examined in a hull for a naval or merchant marine ship. The Civil Aeronautics Board now requires 100% radiography on every wing component of commercial aircraft. With gamma radiography, manufacturers can assure product quality and structural integrity at a considerable savings over x-ray inspection. Portability and freedom from electric power requirements are added advantages.

Gamma gaging is used in measuring thickness during continuous hot working of metal, and for controlling the density of material in process (for example, water content of ore slurries). Since no part of the gage touches the material being processed, there is no problem of corrosion or wear. Gamma-ray-emitting tracers are effective in improving unit operations and investigating all aspects of fluid flow, including detecting leaks, locating obstructions, and measuring corrosion and erosion.

"Intrinsic tracers"–radio-isotopes added directly to the process stream – can accomplish automatic control by providing information on internal chemical changes, mixing rates, material transfer, and concentration of impurities or major constituents.

Where access to material is limited to one side only, gamma reflectance (Compton scattering) methods offer a possible solution. Such devices can provide continuous records of the extent of corrosion along the entire length of a tube or pipe and can be used to measure the wall thickness of drilled engine blocks and other machined parts.

Beta Radiation – Beta gages are useful in controlling continuous production lines – such as rolling of metal strip or sheet – within closer tolerances to improve quality and save material. These automatic radio-isotope controls also permit much faster operation and reduce scrap loss.

Secondary X-Rays – Low-energy (below 100,000 v.) secondary x-rays are generated by the bombardment of metal targets with beta particles from strontium 90, krypton 85, or cesium 137. The high relative attenuation of this radiation provides accuracy not otherwise obtainable in applications such as thickness gaging of thin films and radiography of low-density materials. The isotopic sources which produce these low-energy rays are economical, portable, require less maintenance than x-ray machines, and need no electric power. Secondary x-rays may find use in quantitative, nondestructive determinations of heavy atoms in a light-atom medium – uranium atoms in a U-Al fuel element – or in other continuous analytic problems such as metal in ore flotation streams.

Neutrons – The interaction of neutrons with matter is completely different from the scattering of x-rays and gamma rays; therefore, it offers new potential for inspection or industrial process control. Neutrons interact with the nucleus of an atom and often show extreme discrimination in absorption or scattering between atoms next to each other in the periodic table.

Isotopic neutron sources, consisting of an alpha emitter such as plutonium or a gamma emitter such as radio-antimony mixed with beryllium, have obvious advantages of compactness but provide beams of only 10^6 to 10^8 neutrons per sec.

The relatively small absorption of neutrons in many elements suggests the possibility of examining thicker sections than with x-rays or gamma rays. Since the absorption of neutrons by elements of low atomic number may be much greater than by heavy elements, it is possible to nondestructively test some objects that cannot be examined by electromagnetic radiation. Neutrons also make possible the radiography of assemblies comprising a wider range of light and heavy elements.

*Excerpts from a paper by Paul C. Aebersold and Oscar M. Bizzell, Office of Isotopes Development, U. S. Atomic Energy Commission, presented at Western States Regional Convention of the Society for Nondestructive Testing, Los Angeles, March 1961.

German Commentary on Turbine Failures

*By S. AMMARELLER and P. GRUEN**

Failures in Europe in the 1920's led German metallurgists to use a low-alloy steel of good hardenability, oil quenched and tempered for high strength and ductility. Recently, vacuum pouring has eliminated danger of flaking. (Q26, Q25, J26; AY, 4-51)

FIVE SERIOUS FAILURES of rotors in large electrical generators occurred in America in the early 1950's, and extensive studies of their causes have been published. Notably, a summary of the information so collected up to the end of 1955 was printed in *Metal Progress* for February 1956, and a later recapitulation of the intensive work done by the General Electric Co. in Schenectady was printed in this magazine in August and September 1959. It is natural to reflect seriously as to why similar troubles have not arisen in Europe, and whether differences in the manufacture of rotors, in the selection of materials, and in operating conditions may be responsible.

Actually, four generator shafts broke apart in Germany during the 1920 decade (three of them in the centrifuge testing pit) but after that no more damaging accidents to large rotors of German manufacture have occurred. It will be acknowledged immediately that the operating conditions in Europe are more favorable. With us the customary power frequency of 50 cycles per sec., with the same rotor dimensions, causes less stress. The maximum tangential stress at 3000 rpm. amounts to only 69% of the value existing at 3600 rpm., other conditions being equal.

Investigation of the German failures mentioned above showed that the troubles were partly due to flakes, but also partly to high residual stresses resulting from too rapid cooling during heat treatment. As a result of the developmental work thereupon undertaken, the 28 Ni-Cr-Mo-V 74 steel, which is still customarily used today, was adopted in 1928 for generator shafts and low-pressure turbine rotors. This steel has the following typical analysis: 0.30% C, 1.5% Cr, 2.0% Ni, 0.40% Mo and 0.10% V. It has good hardenability with no tendency toward temper brittleness, and can be drawn at a fairly high temperature. To be sure that only flake-free rotors are installed, rough forgings have been bored axially and the surface of the bore rigidly examined. Furthermore, core drills have extracted radial

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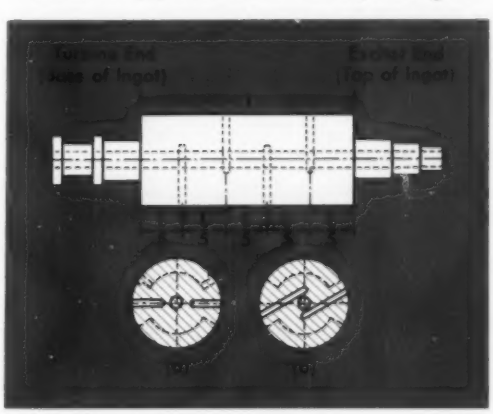
Fig. 1 – Location of Hollow Drill Samples Taken From Large Generator Forgings – (a) Radial or (b) Transverse – at Fifth-Length



Fully Bladed Turbine Rotor, Weighing 21 Tons, Has the Precision of a Fine Watch. (Courtesy General Electric Co.)

samples as indicated at (a) or (b) in Fig. 1; this practice was introduced in 1927.

In the beginning these measures resulted in a larger number of scrapped rotor bodies because internal defects were discovered. They also led to exhaustive investigations of the causes of flake formation, and heat treatments designed to prevent this defect. In this connection we must remember the trail-blazing work at Krupp's, expecially by the late E. Houdremont and his collaborators, in which the combined action of stresses and a supersaturated solution of hydrogen was recognized as the cause of hairline cracks or flakes.

The protracted heat treatments required to prevent such defects, and the risk that dangerous forgings would still be passed even with the increased experience of the steel manufacturers, led to the development of Bochumer Verein's vacuum casting process in 1950, which reduced the hydrogen in the ingot to such a low amount that we can now be absolutely certain that no flakes will form. This greatly shortened the necessary time for heat treatment, since the long diffusion anneal for hydrogen could be safely eliminated. Since 1951 all heavy ingots for highly stressed forgings made at the Bochumer Verein have been cast in vacuum — a practice also followed today by leading manufacturers of heavy forgings. It does not seem necessary to go further into the advantages obtained by vacuum casting, since they have been confirmed by the results already achieved and well known in the United States.

The search for internal defects is now as ever the prerequisite for a decision as to whether a generator shaft or a turbine rotor can be used. In the United States as well as in Europe, ultrasonic testing is widely used as a search method. We welcome the exhaustive work which has

been done on this in the United States, and this applies especially to the facts established by C. D. Moriarty of General Electric's organization – although we do not fully agree with his division of "usable" and "unsuitable" rotors as indicated in his diagram, Fig. 9 in *Metal Progress* of February 1956. We believe that precise boring with hollow drill and investigation of the samples is needed to resolve doubtful instances. (This should always be possible for generator shafts but not always for turbine rotors.) The American work which related to the brittle failure of forgings, especially to the position of the transition temperature and its significance in determining unsuitable steels or improper heat treatments, has proved quite useful. Certainly the work of the personnel at General Electric Co.'s Large Steam Turbine-Generator Dept., and their testing of notched disks and rotors by spinning, has been a most valuable contribution.

Interesting in this connection is the explanation given in *Metal Progress* of February 1956 of the breakdown of the turbine rotor disk which failed at Tanners Creek. It was made of a creep-resistant 1.02-1.13-0.27 Cr-Mo-V steel, similar to our 21 Cr-Mo-V 5 11 steel, which we have manufactured since the middle 1930's under the trademark "BVT 90", making large numbers of forgings from it for high-pressure and medium-pressure turbine rotors up to 60 in. diameter. The heat treatment is decisive for this steel. With suitable heat treatment – that is, not too high a hardening temperature (max. 1800° F. or 980° C.) and a sufficiently high tempering heat (min. 1200° F. or 650° C.) – it has always proved satisfactory. One might conclude that the heat treatment of the Tanners Creek rotor disk was not correct.* It is also known that this Cr-Mo-V steel has a comparatively low hardenability. According to our present understanding, a move in the right direction would be to add some nickel to the analysis to improve its hardenability without appreciably affecting its creep resistance. The elastic limit and ultimate strength of the forgings are thus more nearly the same, even across a large cross section after heat treatment.

We have already mentioned the use of axial bores for finding defects inside large forgings. Based on our experience since the 1920's, axial boring can now be abandoned, unless ultrasonic testing shows such serious indications within the rotor axis that it seems advisable to remove them by boring out the core. If, however, an axial bore is made, it should be large enough so that the wall of the hole participates in the heat treatment – that is, the bore must have a sufficiently large diameter and be made *before* heat treatment. We do not agree in any way with the opinion variously expressed that the chief value of an axial bore and its resulting drill core is to learn something about the characteristics of the interior of the forging *after* its heat treatment. It is known that the working stresses within an axially bored rotor are larger than in an unbored piece, other conditions being equal. This circumstance should therefore be taken into account and the heat treatment should *follow* the boring and should be so designed that the metal in the wall of the bore will have better properties because of the higher cooling speed.

All heat treatments should be done, systematically, with the piece hanging vertically; quenching should be in oil, as has been done by the Bochumer Verein since the 1930's. We cannot understand the advantage of air cooling, which is a delayed cooling. The correctness of our method doubtless results from the circumstance that the transition temperature is shifted to lower temperatures as the cooling speed increases. The correctness of the more rapid liquid quenching can also be deduced from the time-temperature-transformation diagrams. The above-mentioned Ni-Cr-Mo-V steel, for instance, transforms even in the center of very large cross sections after oil quenching in the lower bainite region, and this results in excellent ductility.

Regrettable as the failures may have been with their very great ensuing damage, they have still – because of the investigations and discussions which they have instigated – led to the present situation wherein we possess the greatest possible security in judging the usability of large rotating pieces. We are firmly convinced that, by considering all the assembled results and by intelligent application of modern methods of testing, further rotor failures due to material defects can be avoided.

*EDITOR'S NOTE – As given in *Metal Progress*, this was "a very complicated program extending over 400 hr. between forging and rough machining, and 350 hr. between rough machining and delivery. The latter consisted essentially of solution treatment at 1850° F.; rapid (air) cool to 1000° and then slowly to 600° for a long equilization; then reheating and soaking ('tempering') at 1225° and furnace cooling." About 10,000 psi. residual tensile stress existed at the rim.

Residual Welding Stresses in Aluminum Alloys

*By H. N. HILL**

Fusion welding produces residual stresses in the vicinity of the weld that are about equal to the minimum yield strength in the heat-affected zone. These stresses do not impair the ability of a welded structure to resist static or impact loading. Under some conditions of cyclic loading, the fatigue strength can be affected adversely. In non-heat-treatable alloys, welding stresses can be reduced to a low level by a thermal treatment with little sacrifice in original work-hardened strength. (Q25h, K9; Al-b)

How are residual stresses introduced into a welded structure? During fusion welding, heat softens the metal adjacent to the weld and causes thermal expansion of this material. Cooler metal away from the weld restrains this expansion and introduces compressive stresses parallel to the weld that are high enough to cause plastic deformation. On cooling, the heated region contracts and the yield strength increases. Tensile stresses are thus introduced which must reach a level close to that of the yield strength of the material before any relief resulting from plastic deformation can occur. These tensile stresses are balanced by compressive stresses in regions away from the weld.

Importance of Residual Stresses

Residual stresses in a weldment are important only to the extent that they influence behavior. Weldable aluminum alloys have enough ductility to permit residual stresses to equalize by plastic yielding before rupture occurs. Some ferrous materials, although ductile under normal conditions, become brittle at low temperature under rapidly applied loads. Here, residual tensile stresses may be detrimental to mechanical properties. It is not unnatural to wonder if aluminum containing residual tensile stresses has any tendency toward decreased ductility under the same conditions.

Buckling of welded structures is another aspect of behavior that might be affected by residual stresses. In the plastic range, buckling strength depends on the shape of the compressive stress-strain curve, and the shape of this curve can be influenced by residual stresses.

Of greatest concern is the possible effect of residual tensile stress – in and adjacent to the weld – on fatigue strength. These stresses raise the level of the mean stress in the critical region of the weld and therefore decrease the fatigue life.

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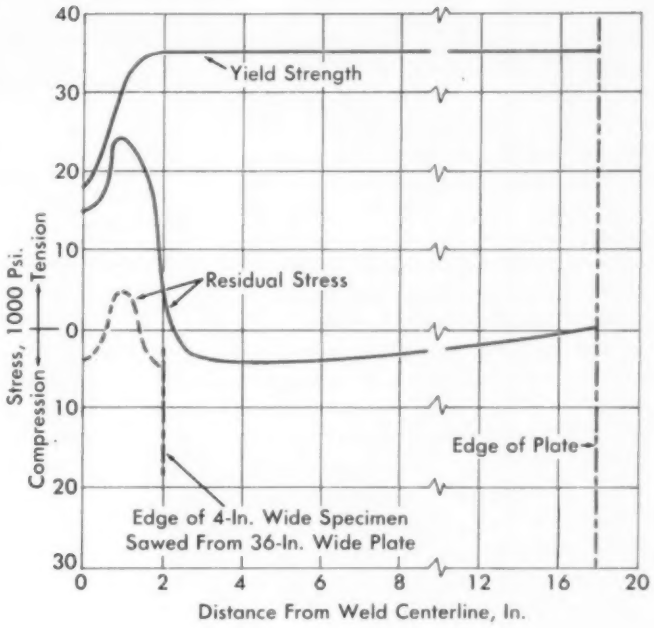
Fig. 1 – Distribution of Yield Strength and Residual Stresses in a Longitudinally Welded 5456-H 321 Plate 36 In. Wide and ½ In. Thick. The dotted line shows the level of stress in a strip 4 in. wide cut from the panel; this relieved residual welding stresses



Finally, some materials, including certain aluminum alloys, are susceptible to stress-corrosion. It is known that stress-corrosion can occur in cold worked aluminum-magnesium alloys subjected to sustained stress and a corrosive environment. This naturally raises the question of whether or not residual tensile stresses from welding might aggravate a sensitivity to stress-corrosion.

Aside from all these possible effects on behavior, residual stresses are definitely undesirable in welded parts to be machined. Welding frequently disturbs the balance of the residual stress pattern, resulting in warping of the part.

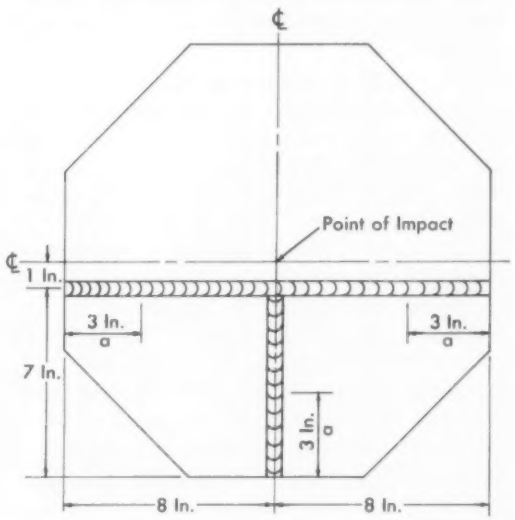
This article deals only with longitudinal welding stresses, that is, those parallel to the weld bead. Tests were conducted on 5456-H 321 plate – the strongest weldable aluminum magnesium alloy commercially available. All welds were made employing alloy 5556 consumable electrodes and inert-gas shielding. Figure 1 shows a typical distribution of residual stresses in a 36 by 48-in. panel formed by groove-welding two 18 by 48 by ½-in. plates. Variation in yield strength of the material with distance from the centerline of the weld is also shown. The residual tensile stresses in and adjacent to the weld approach the yield strength. These tensile stresses are confined to the region in which the heat of welding has lowered the yield strength of the material.

Impact Strength at Low Temperature

Falling-weight impact tests were made on welded and unwelded 5456-H 321 plate, 0.4 in. thick. The impact specimens (Fig. 2) were supported on a ring anvil with an 11¾-in. diameter opening, and were struck at their center with a 257-lb. falling weight fitted with a striking block having a ¾-in. spherical nose.

Half of the specimens were stress relieved

Fig. 2 – Details of Impact Specimen. At "a", the weld bead was removed on the bottom side only



at 550° F. for 1½ hr. A maximum residual tensile stress of 24,000 psi. was measured adjacent and parallel to the weld. In stress-relieved panels, the maximum stress was 4000 psi.

Test results (Table I) show no significant improvement for stress-relieved panels over as-welded plates when tested at room temperature. As-welded plates behaved about the same at −280° F. as at room temperature.

Table I – Falling-Weight Impact Tests on Welded 5456-H321 Plates

Condition	Test Temperature	Critical Height of Drop★	Permanent Deformation
As welded	Room	44 in.	0.7 in.
As welded	−280° F.	42	0.6
Stress relieved	Room	44	0.8

★Average between lowest height that caused a crack and highest drop that did not cause a crack.

In a compression member with a longitudinal weld, effect of residual stresses is complicated by tensile stresses in the region of reduced yield strength at and near the weld. Column tests were made on specimens of 5456-H 321 (8 in. wide, ½ in. thick) formed by butt welding two 4-in. wide plates. Maximum residual stress was 17,000 psi. in the as-welded plates and 2500 psi. in stress-relieved specimens. The thermal treatment reduced the compressive yield strength outside the heat-affected zone by 10%. The presence of residual welding stresses (Fig. 3) did not decrease the buckling strength. In fact, the stress-relieved specimens show lower strength, reflecting the decrease in yield strength accompanying thermal treatment.

Residual Stress Affects Fatigue Strength

Axial stress fatigue tests were made on plate specimens containing a longitudinal weld as shown in Fig. 4. To obtain the maximum level of residual stress, both halves of the fatigue specimen were machined to final dimension before being joined by a groove weld. Residual stress measurements were 17,500 psi. for as-welded plates and 2000 psi. for stress-relieved specimens.

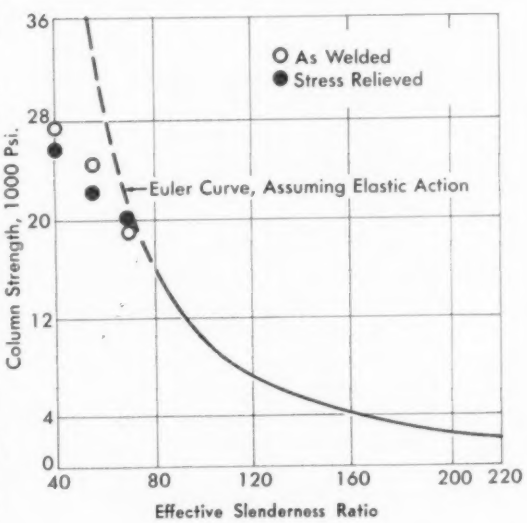
Test results at three stress ratios are shown in Fig. 5. The effect of the residual stress depends on the maximum value and also on the stress ratio of the applied stress. For a stress ratio of 0.5 (when applied cyclic stress varies from a given tensile stress to twice that stress) there is little difference in fatigue strength between as-welded and stress-relieved specimens, at least out to 1×10^7 cycles. At −0.5 stress ratio (when applied stress varies from a compressive stress to a tensile stress twice the magnitude) stress-relieving definitely increases fatigue strength. At 1×10^7 cycles, fatigue strength of stress-relieved specimens is about 60% greater than that of as-welded specimens. At a stress ratio of zero (applied stress varies from zero to a given tensile value) fatigue strength at 1×10^7 cycles increases about 40% as a result of relieving residual stresses by thermal treatment.

The effect of residual welding stresses on fatigue strength decreases as the maximum applied tensile stress increases and the number of cycles of failure decreases. Convergence of the two curves when the stress ratio is zero suggests that there would be no difference in strength at 1×10^5 cycles. Convergence of the curves for −0.5 stress ratio would occur at some lower number of cycles. Note that the *static* strength of as-welded and stress-relieved specimens is about the same.

Stress Corrosion Does Not Occur

Panels of 5456-H 321 containing a longitudinal butt weld were exposed by alternate

Fig. 3 – Results of Column Tests on ½-In. Thick 5456-H 321 Plate Containing Longitudinal Welds. The data show that buckling strength is not decreased by the presence of residual stress



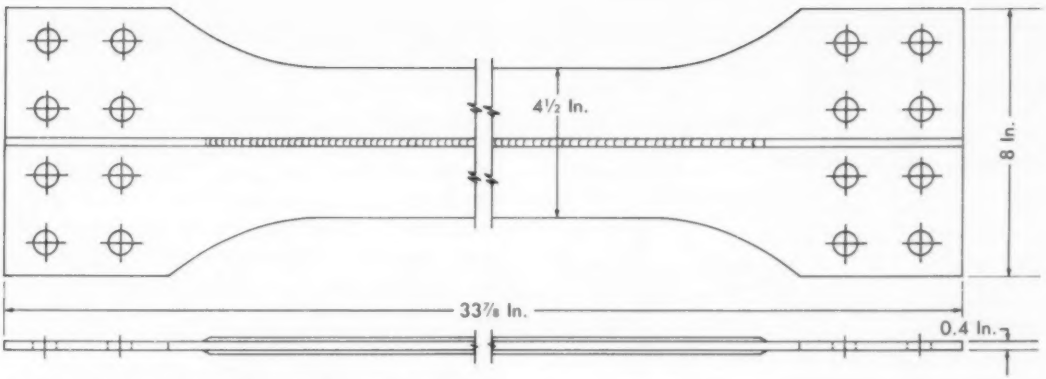


Fig. 4 – Longitudinally Welded Fatigue Specimen. Each half was machined to shape before welding

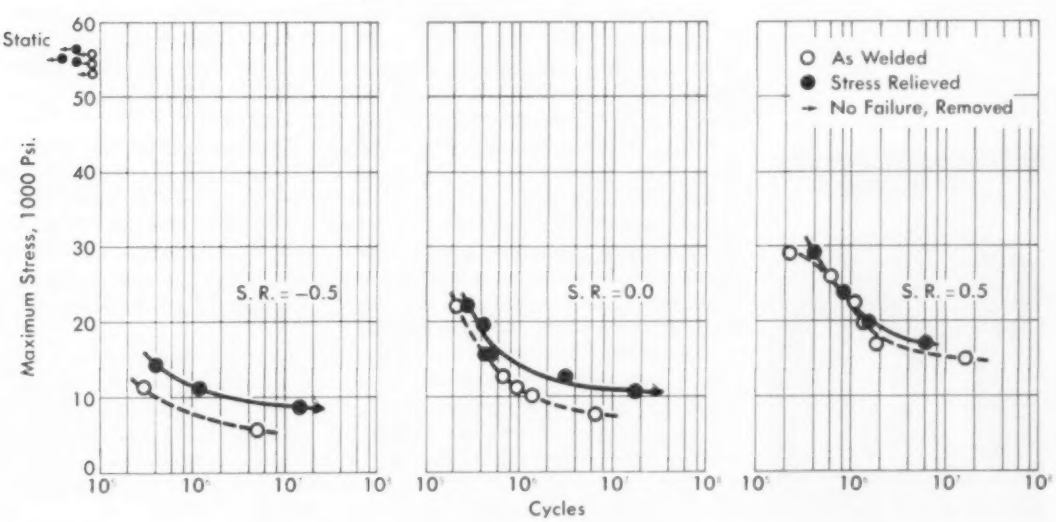
immersion in a 3½% NaCl solution. Some samples were exposed in the as-welded condition while others were thermally stress relieved. Residual tensile stresses were 17,000 psi. in as-welded and 2000 psi. in stress-relieved plates. Panels of each group, given a sensitizing treatment by heating at 212° F. for one week, were also included. Experience has shown that this treatment – which reduces the maximum residual tensile stress by about 1000 psi. – develops any latent stress-corrosion tendency. Some specimens were subjected to bending which produced a nominal applied bending stress of about 21,000 psi.; others were exposed without externally applied stress. These specimens have been exposed for 11 months, with no sign of stress-corrosion cracking and only a very mild surface attack.

Other stress-corrosion specimens of welded 5456-H 321 plate, sensitized and stressed at 75% of the yield strength, have undergone alternate immersion tests in 3½% NaCl solution for 18 months without stress-cracking. In such tests, no cracking in this period of time is generally interpreted as indicating a lack of susceptibility to stress-corrosion.

Thermal Relief of Residual Stresses

In those circumstances where residual stresses are known to be harmful to non-heat-treatable aluminum alloys such as 5456, a thermal treatment can be used to reduce them. To be useful, such a treatment should have no serious adverse effect on strength or other properties of the material. For practical

Fig. 5 – Effect of Stress Relief on Fatigue Strength of 5456-H 321 Longitudinal Butt Welds. Stress ratio, S.R. $= \frac{\text{min. applied stress}}{\text{max. applied stress}}$



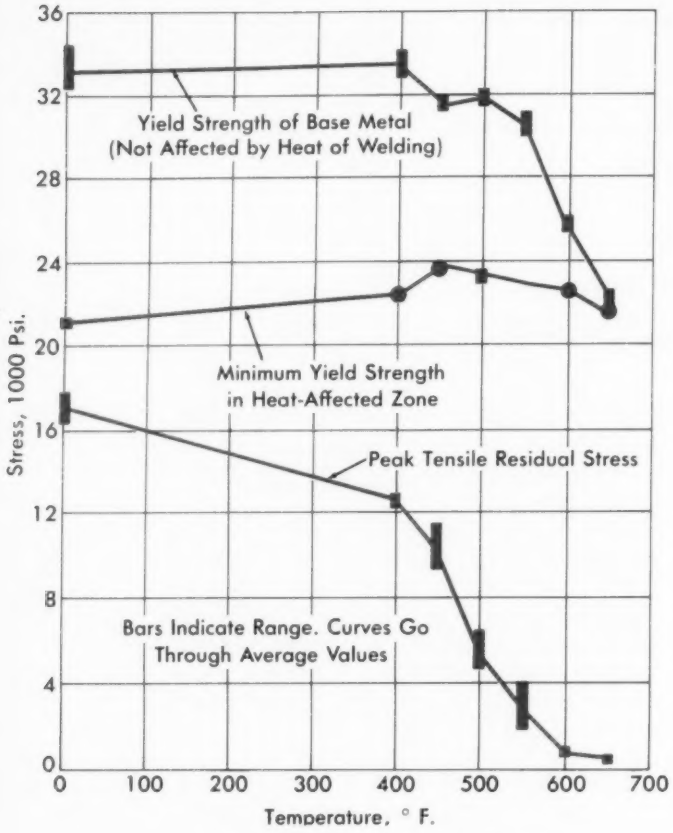


Fig. 6 – Effect of Temperature on Yield Strength and Residual Stress of ½-In. Thick 5456-H 321 Welded Plate

reasons, time and temperature of treatment should be kept to a minimum.

We determined the effect of temperature on relief of residual stresses and on mechanical properties using 8-in. by 21-in. panels formed by butt welding two ½-in. thick 5456-H 321 plates. Results are shown in Fig. 6. At 400° F., there was no decrease in yield strength of the base material; minimum yield strength in the heat-affected zone improved slightly, but residual stress was reduced only by about 25%. A temperature of 500° F. or higher was required to produce an appreciable reduction in residual stress. At 550° F., the residual stress was reduced more than 80%, with less than 10% loss in base-metal yield strength. Tensile strength was less affected than yield strength. Temperatures above 550° F. resulted in significant reductions in yield strength of the base metal. Essentially complete annealing occurs at 650° F., with almost 100% relief of residual stresses.

For the tests described here, we adopted a thermal treatment of 550° F. for 1½ hr. (total heating time). Further investigation is required to establish recommended thermal treatments for weldments of the various non-heat-treatable aluminum alloys in different tempers. However, residual stresses in 5456-H 321 weldments can be reduced about 75% by holding the part at a temperature of 525° F. for 15 min., with only a 5 to 10% loss in yield strength of the base material.

On the Cover

Impacts in Color

The colorful cylindrical shapes on this month's front cover are a preview of "Varaflow". This special form of aluminum, now being studied by the Alcoa Research Laboratories, incorporates integral variegations of color change – not unlike the color flow of marble cake or ripple ice cream. It is in fabricating that the flow pattern of the alloy is created.

After fabrication (the impact process was employed to create the prototypes on the cover), the part is given an anodic treatment which is the key to attaining color with "Varaflow". According to Alcoa's industrial design department, the potential color range of the alloy is broad: Natural aluminum, light to medium gray, a warm (almost black) gray and true gold. All these can be produced with a clear anodizing process. If color anodizing is employed, the integral color variations of the material act to modify the tones and values of the anodizing color.

The potential for manufacture of the new material is being explored by Alcoa's metallurgy and production group. If this proves feasible, the designer will have a new material with a unique decorative potential for furnishings, trim panels, furniture components and many other products. The striking cover photograph which protrays the parts against a background of the New York skyline at night was provided by Samuel L. Fahnestock, Alcoa's manager of design.

How to choose a metal for high-temperature service

In every sense, "the heat's on" and "the pressure's on" when metals go to work at high temperatures. The basic trend in processing equipment has been toward higher pressures, higher temperatures, and more corrosive conditions.

That's why questions like these are being asked today: What metal is used within the core of a gas-cooled reactor where operating temperatures go up to 1700°F? What metal is used for the "skin" of a missile that must take supersonic heats from 400° to 600°F . . . and be the structural framework for 130 tons of dead weight? What metal is used to withstand the corrosion of hot ammonia gas at 900°F? What metal is used for strength and corrosion resistance above 1000°F?

The answer, in each case: Nickel Stainless Steel.

Nickel works as a strengthening and toughening agent. In steel it promotes the formation of austenite, which is stronger and more stable at high temperatures than ferrite. Nickel steps up steel's resistance to oxidation, carburizing, nitriding and thermal fatigue.

The war against corrosion. High-temperature equipment is exposed to a great many different atmospheres and corrosive conditions. Many materials coming from high-temperature processing and handling must be delivered uncontaminated by the products of corrosion. Nickel stainless steels are especially good for fighting corrosion . . . perform well under those oxidizing conditions harmful to unalloyed steel. The stainless steels possess the ability to protect themselves with oxide films that form a shield against corrosion. And *stainless* steel, as the name implies, stays brighter, cleaner . . . and the protective "oxide layer" is less likely to be broken or reduced by pitting or scaling.

What strength means at high temperature. By a mechanism known as "creep" metals at elevated temperatures flow plastically though subjected to stresses below their yield strength, as determined by short-time tensile tests. The creep strength of nickel stainless steels is an important reason for their increasing use in a variety of high-temperature operations. Both *time* and *stress* are design factors at high temperatures. The most generally useful data are those for creep and rupture—one or the other is the basis for most allowable stress values in design work.

The chart below gives the creep and rupture strength data of two nickel stainless steels that have found wide acceptance in high-temperature service:

	CREEP STRENGTH			
	1000°F		1500°F	
AISI TYPE	1% 100,000 hrs,psi	1% 10,000 hrs,psi	1% 100,000 hrs,psi	1% 10,000 hrs,psi
310	17,500	32,500	1,250	3,500
316	14,750	24,500	1,800	4,200
	RUPTURE STRENGTH			
	1000°F		1500°F	
AISI TYPE	100,000 hrs,psi	10,000 hrs,psi	100,000 hrs,psi	10,000 hrs,psi
310	21,000	25,000	1,600	2,800
316	--	--	1,600	3,400

Don't stop at creep and rupture strength . . . other critical questions must be considered in the selection of metals for high-temperature service. They include:

- high temperature ductility
- short-time tensile properties to help evaluate resistance to momentary overloads
- thermal shock resistance

Before selecting a metal for a specific service ask yourself these questions:

- ☐ What is the maximum temperature of operation?
- ☐ What kind of temperature cycling will occur?
- ☐ What maximum load will be encountered? Will it be constant or cyclic?
- ☐ What types of atmosphere or other corrosive conditions?
- ☐ What size or shape of the parts or sections?
- ☐ What further processing will be done, such as welding or machining?
- ☐ What abrasive or wear conditions will be encountered?

The nickel stainless steel family can serve you in a wide range of high-temperature operations. That's why it's best to bring your metal problem to Inco's High Temperature Engineering Section. They are fully prepared to give you practical answers on the metal that will work best in your application. A note to Inco will bring you the "High Temperature Worksheet" to guide you in describing your metal problem.

LITERATURE

The publications listed below will provide more detailed information on choosing metals for high-temperature service.

PUBLICATION NUMBER	NAME
A266	Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications
A227	Stainless Steel for Pressure Vessels
	High Temperature Corrosion in Refinery and Petrochemical Service
A164	Thermal Expansion Characteristics of Stainless Steels Between −300°F and 1000°F
A248	Compilations of Chemical Compositions and Rupture Strengths of Super-Strength Alloys

A complete listing of Inco publications and technical bulletins can be obtained by writing for "List A" to:

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INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Machining Udimet 500, Solution Treated and Aged to Bhn. 360

Operation	Tool Material	Tool Geometry (*a*)	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-Land (*b*)	Cutting Fluid
Turning	C-1 or C-2 carbide	SR: 5°; SCEA: 15°; BR: 0°; ECEA: 15°; Relief: 5°	½-in. square throwaway holder with mechanical chip breaker	0.100 in.	—	0.009 in./rev.	55 ft./min.	34 min.	0.016 in.	None
Turning	T-15 HSS	SR: 15°; SCEA: 0°; BR: 0°; ECEA: 5°; Relief: 5°	⅝-in. square tool bit	0.060	—	0.009 in./rev.	15	48 min.	0.060	Soluble oil (20:1)
Face milling	T-15 HSS	AR: 10°; ECEA: 5°; RR: 10°; Cl: 10°; CA: 45°	4-in. diam., 2-tooth face mill	0.060	2 in.	0.005 in./rev.	25	26 in./tooth	0.016	Soluble oil (20:1)
Side milling Down milling setup	T-15 HSS	AR: 10°; ECEA: 5°; RR: 10°; Cl: 10°; CA: 45°	6-in. diam., 3-tooth face mill	0.060	1¾	0.010 in./rev.	20	25 in./tooth	0.016	Soluble oil (20:1)
Slot milling Down milling setup	C-2 carbide	AR: −5° bi-negative; RR: −5°; ECEA: 3°; CA: 45° × 0.030 in.; Cl: 12°	6-in. diam., single-tooth, inserted-tooth cutter	0.125	1	0.005 in./rev.	100	27 in./tooth	0.040 localized wear	None
End milling	T-15 HSS	35° RH helix; CA: 45° × 0.030 in.; Per. Cl: 12°	¾-in. diam., 4-flute end mill (*c*)	0.250	¾	0.002 in./tooth	30	54 in.	0.012	Soluble oil (20:1)
Drilling	M 33 HSS	2-flute, 118° crankshaft point; 7° clearance	¼-in. diam. drill, 2½ in. long (*d*)	0.500 through hole	—	0.001 in./rev.	20	32 holes	0.016	Highly sulfurized oil + light machine oil (1:1)
Tapping	M-10 HSS	2-flute, plug chip driver tap; 75% thread	5/16-18 NC plug tap	0.500 through hole	—	—	5	18 holes	Tap breakage	Highly chlorinated oil + inhibited trichloroethane (3:1)
Tapping	M-10 HSS	2-flute, plug chip driver tap; 70% thread	5/16-18 NC plug tap	0.500 through hole	—	—	5	32 holes	Tap breakage	Highly chlorinated oil + inhibited trichloroethane (3:1)

(*a*) AR = axial rake; RR = radial rake; CA = corner angle; SR = side rake; BR = back rake; SCEA = side-cutting edge angle; ECEA = end-cutting edge angle; Cl = clearance.
(*b*) Wear on the peripheral flank of the cutter.
(*c*) For end mills ½-in. diam. and over. Flute length should be short as possible for maximum rigidity.
(*d*) Use stub length drills whenever possible.

Source: Metcut Research Associates

Electrolytic Polishing of Refractory Metals

*By F. R. CORTES**

This article discusses a versatile solution, composed of small amounts of sulphuric and hydrofluoric acids in methanol, which can be used to electropolish four refractory metals – molybdenum, tungsten, tantalum and columbium. Grinding and polishing procedures are also described. (M20p; Mo, W, Ta, Cb, EG-d)

THOUGH THE DEVELOPMENT AND APPLICATION of the refractory metals (particularly molybdenum, tantalum, tungsten and columbium) has proceeded rapidly in recent years, metallographic techniques have not kept pace. As a result, we at Universal-Cyclops Steel Corp. found it necessary to develop a metallographic technique which could be applied to the demands of production control as well as to research and development programs. After an extensive investigation, during which many different polishing methods were studied, we came up with a versatile electrolyte. Composed of 5% H_2SO_4 and 1.25% HF in methanol, this new electrolyte has been highly useful since its inception.

When we began our work, electrolytic polishing had to be considered because most refrac-

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Table 1 – Procedure for Polishing Refractory Metals

PROCEDURE*	COLUMBIUM	TANTALUM	MOLYBDENUM	TUNGSTEN
Amp. per sq.cm.	4.6 to 5.4†	4.6 to 5.4†	4.4	4.4
Voltage	50 to 60	60 to 80	50 to 70	50 to 70
Time	10 to 20 sec.	15 to 25 sec.	6 to 12 sec.	8 to 15 sec.
Flow rate	Medium fast	Medium fast	Medium fast	Medium fast
Temperature	<75° F.	<75° F.	<75° F.	—

*For all metals the electrolyte consists of 5% H_2SO_4 and 1.25% HF in methanol.

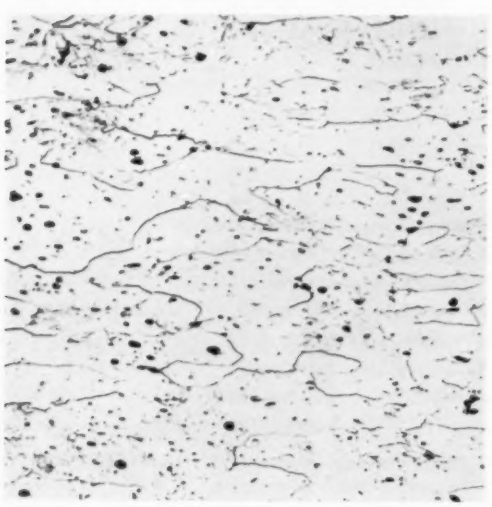
†Maximum area polished, 0.06 sq.in.

tory metals are relatively difficult to polish by hand. For example, commercially pure as-cast, wrought, and recrystallized tantalum and columbium are hard to polish because they are relatively soft. Since these metals do not work harden appreciably, flowed metal surfaces are difficult to remove even when the metal is in the wrought condition. Pitting also occurs during polishing and etching, being aggravated by the presence of polygonized structures in arc-cast tantalum, columbium, molybdenum and tungsten.

Molybdenum is commonly polished mechanically when in the worked and recrystallized conditions. In the as-cast state, molybdenum is difficult to hand polish; however, it can be electropolished by any of a number of electrolytic methods that have been available for several years.

Tungsten is the easiest of the four metals to hand polish since it abrades evenly and remains relatively free of worked metal surfaces. It is also easily electropolished in several alkaline and salt solutions.

Fig. 1 – Specimen From Swaged Bar of Thoriated Tungsten After Electropolishing With the New Solution. Thorium oxide and porosity are evident in the structure. Etchant: 15% HNO_3 and 3% HF in water; 200 ×



Several Electrolytes Evaluated

In attempting to develop an electrolytic polishing* technique for tantalum and columbium, we first evaluated those electrolytes which had proven satisfactory for other refractory metals. (Initially, it was decided to eliminate the very corrosive and dangerous solutions from consideration.) Various concentrations of perchloric acid and alcohol were tested, with fair results being obtained with a solution of 30 ml. $HClO_4$ and 740 ml. methanol. In all concentrations, an insoluble, flaky film formed on the surface of the specimen. However, the aforementioned composition produced a polished surface when the film was removed. In some instances, particularly with as-cast columbium, the film was partially adherent, and results were not consistent because of this.

Viscous liquids, such as glycerol, were then added to several common acid-alcohol electrolytes in an attempt to form or increase the thickness of the anodic film theoretically needed for polishing. However, the drop in cell current caused by such additions either increased anodization and formation of a tight surface film, or caused the specimen to be etched rather than polished.

It seemed that we needed a low-viscosity electrolyte with an alcohol base in which the acid addition alone would maintain the polishing film. Since the experimental electrolytes

*Our laboratory uses an early model of a commercial electropolisher (Disa Electropol).

were, for the most part, mixtures of viscous H_2SO_4 and H_3PO_4 acids, low acid concentrations appeared to be a step in the right direction. Therefore, we aimed at a dilute acid-alcohol electrolyte which would limit the formation of, or dissolve, anodic reaction products such as columbium or tantalum oxides and salts. This led to a solution composed simply of 5% H_2SO_4 and 1.25% HF acids in methanol. (Table I lists the procedures which were most successful with our electropolisher.) This composition falls within a "critical range" of total acid concentration, from a minimum of about 4% to a maximum of about 8% by volume. Below a total acid content of 4%, the specimen is severely anodized and discolored; above 8%, both anodization and etching occur. To obtain satisfactory results, the H_2SO_4 to HF ratio should range between 2:1 and 10:1.

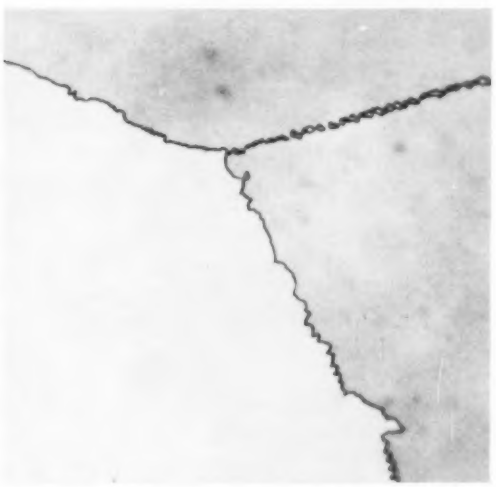


Fig. 2 — As-Cast Molybdenum Polished by the New Technique. Note the molybdenum carbides at the grain boundaries; they are not polished out or pitted by electrolytic action. Etchant: Murakami's; 500 ×

Bath Temperature and Flow Rate

It should be noted that bath temperature is to be kept at, or somewhat below, room temperature. When the temperature of the electrolyte rises above 75° F. (due to ionization of acids during mixing or heat evolved during polishing), a slight surface film may appear on the polished surfaces accompanied by an "orange-peel" appearance under the microscope. This is particularly critical with thin sheet because the electrolyte must then also act as a coolant in order to keep the relatively small mass from overheating.

The "medium fast flow rate" indicated in the table is approximately a 14 to 16-cm. liquid electrolyte column pressure. Variation in flow rate has a more pronounced effect on the quality of polish obtained on tantalum and columbium (which are soft) than on tungsten and molybdenum. With high flow rates, polishing striations appear parallel to the direction of electrolyte flow across columbium and tantalum surfaces. Such striations do not occur on molybdenum and tungsten surfaces.

With slower flow rates, surfaces polished more evenly, but the minimum velocity was limited by the characteristics of the electrolyte. That is, as flow rate decreases, arcing occurs. Cell resistance increases and causes overheating, along with a proportional decrease in cell current. The latter effect is believed to be a result of the low acid concentration in methanol, a nonelectrolyte. In this solution, high flow rates are required for necessary electrical conduction and current densities.

As the electrolyte is used, it appears to "age", and the quality of the polished surface improves. The reason is unknown, but it may be related to an increasing solution or suspension of metal salts or oxides in the electrolyte.

Polishing Methods Are Conventional

Specimens are wet ground through silicon carbide papers, and finished on either the 600-grit, 3/0 or 4/0 papers. Surface appearances of electropolished tantalum and columbium improved considerably when specimens were finished on the finer 4/0 paper, though results were relatively good when 3/0 or 600-grit finishes were used. With regard to scratches on the surfaces, tungsten and molybdenum also exhibited improved polishes when preliminary hand polishing was concluded on the finer 4/0 metallographic paper. In all instances, the specimens were "circled" on the final metallographic paper to remove directional polishing abrasions.

Coarse surfaces, which are usually the result of polishing striations forming parallel to flow direction of the electrolyte, can be eliminated by longer electropolishing times with decreased flow rates. Two other techniques will help to

improve polished surfaces of tantalum and columbium. Mechanically polished surfaces can be either etched prior to electropolishing, or the specimen can be electropolished and then rotated 90° and repolished. In this manner, the striations formed during the initial polishing operation will be transverse to the direction of electrolyte flow.

Structures Are Well Defined

Figures 1, 2, 3, and 4 illustrate typical structures obtained with the listed procedures. For example, sintered and swaged tungsten bar is shown in the micrograph Fig. 1. The structure consists of heavy dispersion of thorium oxide and other impurities plus a small amount of porosity. The degree to which the impurities (or precipitates) are removed during polishing depends primarily upon the polishing time; they can be loosened if too much of the surrounding matrix is polished away.

Commercially pure as-cast molybdenum (Fig. 2) contains a small amount of molybdenum carbide which is easily seen in the photomicrograph. The carbides have formed as grain-boundary precipitates, and are not polished out or pitted by electrolytic action.

Figures 3 and 4 are typical of the quality of micrographs which can be obtained from tantalum and columbium after electropolishing. In the as-cast state, these metals are difficult to prepare since coarseness (due to directional flow of electrolyte) and pitting are more pronounced.

This new electrolyte has several advantages which make it attractive to the metallographer. First, it is satisfactory for all four of the refractory metals – tungsten, molybdenum, tantalum and columbium. Since solutions do not have to be changed when different metals are polished, much time is saved. Second, the cost of the electrolyte is negligible since the concentration of acid is low; it also can be stored for several weeks. Last, but of primary importance, the dilute acid solution is relatively noncorrosive to equipment, and can be safely handled and stored with the usual care. There is no danger of explosion unless the hydrogen gas (emitted during polishing) is prevented from escaping, and is ignited by malfunctioning equipment.

All things considered, this seems to be an excellent solution for electropolishing refractory metals. Its advantages far outnumber its drawbacks, as far as we can determine. Many laboratories should find it useful.

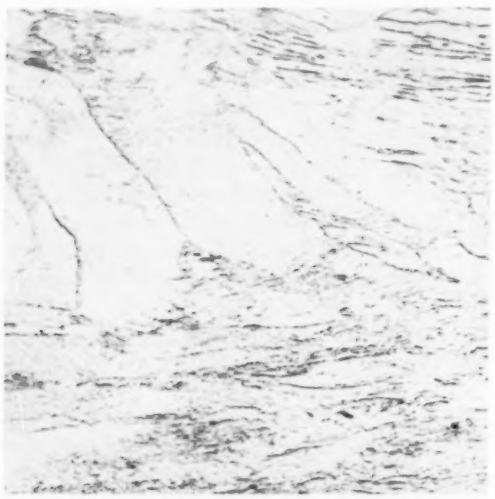


Fig. 3 – As-Forged Tantalum. In the as-cast condition, this metal is more difficult to prepare; coarseness and pittings are more pronounced. Etchant: 5 parts HNO_3, 1 part HF, 10 parts H_2O; 200 ×

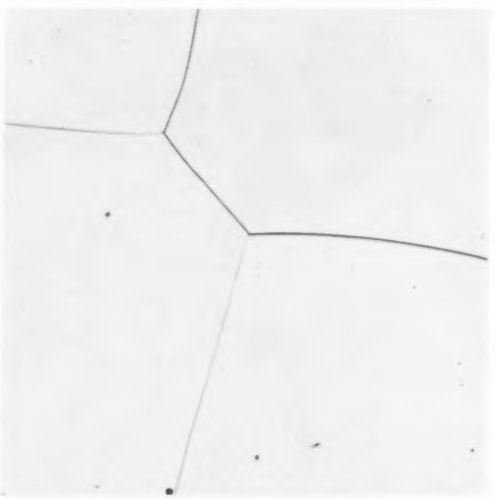
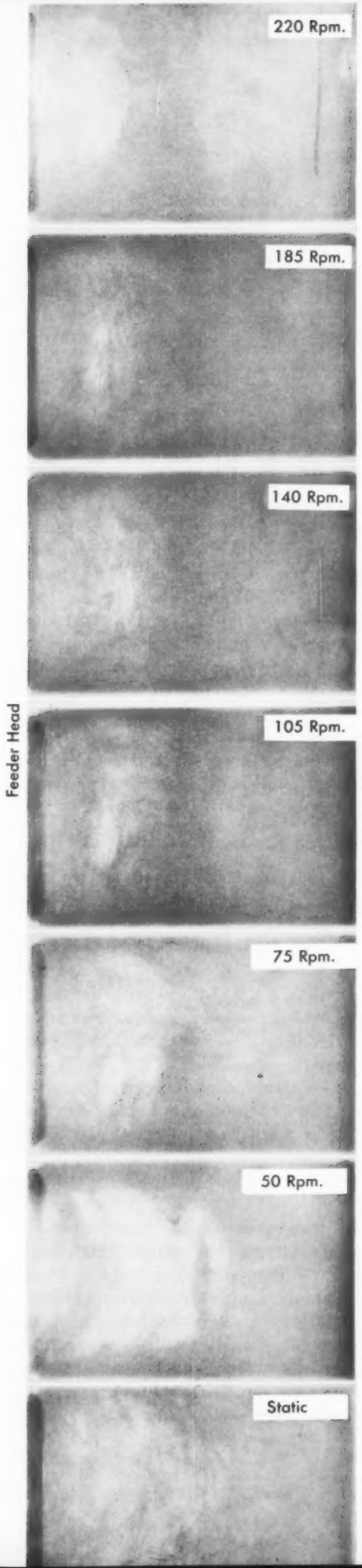


Fig. 4 – Arc-Cast Columbium. Though not evident here, uneven surfaces are sometimes encountered when polishing as-cast columbium and tantalum by this method. Etchant: 5 parts HNO_3, 1 part HF, and 10 parts H_2O; 200 ×



Centrifugal Casting of Thin-Walled Magnesium Parts

By WARREN C. SMITH*

For complex shapes difficult to produce, the centrifugal process is providing sound magnesium castings that are often metallurgically superior to those produced by other casting methods. (E14; Mg)

THE ADVANTAGES OF THE CENTRIFUGE, which produces superior castings economically, have to some extent been overlooked by the magnesium foundry industry. Many authorities have stated that anything cast in the centrifuge can be produced more easily some other way. Gating and risering, feeding and chilling, and selection of molding media are so versatile by other methods that these may outweigh the advantages of the centrifuge. For many designs this is probably true.

There are certain parts, however, which are difficult to cast by other methods, and which then require expensive machining. We are finding that the centrifugal process, employing permanent molds, is more effective for rocket and missile fins with knife edges, thin-walled electronic module cases and covers, impellers and blades, and almost any cast configuration requiring thin webs which, by other methods, would not fill without misruns and cold shuts.

Sound Structure Obtained

While some of the important advantages of a centrifuge are obviously economic and mechanical, metallurgical improvement in the cast structure is also important. A series of AZ 91 C alloy slabs – 6 in. long, 5 in. wide and 1 in. thick – were cast at various rotational speeds up to 220 rpm. (4180 surface ft. per min.). The test slabs were end-chilled with a removable chill (water quenched after each pour).

The resulting radiographs – using a fine-grained

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Fig. 1 – X-ray of Test Slabs Cast at Various Rotational Speeds. Microporosity moves toward feeder head as rotational speed increases to 140 rpm.

film and an x-ray tube with a beryllium window for optimum contrast – indicated a uniform dispersion of microporosity in slabs cast statically, but microporosity gradually moved toward the feeder head as the speed (and centrifugal force) increased up to 140 rpm. (2650 surface ft. per min.).

In the statically cast slab (Fig. 1), we see that discontinuities are uniformly dispersed, except in the immediate area of the chill which we know will normally be free of microporosity. However, the radiograph of the casting spun at 50 rpm. (950 surface ft. per min.) shows that the discontinuities have migrated toward the centerline. As we increase speed from 75 to 140 rpm., microporosity is further reduced in area, moving to the centerline and toward the feeder head. Higher speeds show little additional change.

Why does this improvement occur in direct proportion to increases in rpm. up to 140? The radiographs show that, at all rotational speeds, discontinuities occur at the centerline in contrast to a uniform dispersion in static castings. This is due to rapid chilling of surface areas where heat transfer is not interrupted by shrinkage gaps in the mold-casting interface. The molten metal is continually pressing against this interface, preventing the casting from shrinking away from the heat-conducting mold wall as it does in the static permanent-mold process. This would account for the centerline nature of the discontinuities and the fact that they decrease in area as rotational speeds increase. The chill condition is so rapid that gases in solution do not precipitate, whereas the center portion of a test slab, toward the header, retains enough heat to allow gas precipitation.

More Rapid Chill Is Obtained

Does prevention or delay in the formation of a shrinkage gap result in more rapid chilling in the centrifuge than in a static mold? We believe the more rapid chill of the centrifuge is demonstrated by the ability of the process to fill a mold cavity containing thin-wall sections – impossible to cast in a static mold – and do it at lower mold and pouring temperatures. The fact that the colder mold is properly filled is a guarantee that a quicker chill results. Our company has had little success in casting magnesium parts (with thin walls less than 0.125 in.) in sand and static permanent molds; but centrifugal equipment can produce wall thicknesses down to 0.080 in. in some designs. By solidifying almost instantaneously, these parts show very little microporosity.

Mechanical Properties Are Better

Since grain size is directly proportional to rate of chill, it seems logical to expect centrifugal casting to improve mechanical properties as well as produce sounder castings. Test results have indicated that mechanical properties near the feed end of cast test slabs are substantially improved as centrifugal force is increased. The tensile strength increased from 20,000 to 36,000 psi. (static versus 105 rpm.). Elongation also increased from 1% to about 4% as the speed of rotation increased. In contrast, properties at the chill end and center level off with no significant change after a sharp rise from static conditions to 50 rpm.

We believe these results indicate that the centrifuge process provides metallurgically superior castings in shapes which are difficult to cast by other methods. In addition, the process may be relied upon to produce castings with closer dimensional tolerances than conventional permanent-mold operations because less refractory mold wash is necessary and it need be reapplied less frequently.

Mechanical and Economic Advantages

The centrifugal process has many mechanical and economic advantages, including faster casting cycles, filling of thinner webs, achievement of more intricate configurations and finer detail, and better surface smoothness. The process can also produce good castings with the more sluggish alloys. In certain configurations, for example, HK 31, ZH 62 and QE 22 will cast almost as readily as AZ 91 C.

On the economic side, and assuming suitable rotational and cycling controls are built into the equipment, centrifugal casting may soon compete favorably in the commercial field with die casting. It produces castings with close fidelity to mold details, and it is capable of production rates equal to most die-casting operations. The centrifuge has certain design limitations – H & S is not closing down its sand or permanent-mold foundries in our new enthusiasm for the electronically controlled centrifuge. Still, this type of machine (with its supporting system) provides unique advantages in casting military and commercial hardware in many "difficult" alloys and configurations.

No. 8 in a Series on Better Finishing

How to Get the Most From Phosphating Systems—I

*By GEORGE H. PIMBLEY**

Progress in research combined with the lessons of practical experience has taken much of the guess work out of phosphate coatings and how to apply them. In this, the first of a three-part article, the author describes some of the recommended practices for zinc phosphate dip baths. In subsequent issues techniques for getting best performance from zinc phosphate spray systems and from manganese and iron phosphate systems will be presented. (L14b)

IT HAS BEEN SAID that Roman soldiers in ancient Germany found certain deposits of phosphate-bearing earths which proved effective in removing rust from their armor and in preserving it against the weather. Perhaps inspired by that tale, officers of the British army employed phosphoric acid about a century ago to maintain their swords in bright condition. Thus, the art of protecting metals by depositing a phosphate coating on them is certainly not new, but it has only received wide application in the last three decades. With this growth has come a broad scientific foundation upon which to build better phosphating compounds and processes. However, much remains to be done in areas of research as well as in the application of the basic principles and good operating practices of which we are already aware.

Today, we are able to apply phosphate coatings on most articles of iron and steel and parts coated with zinc and cadmium. They must

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have accessible surfaces and be of such size and shape as to allow introduction into processing baths or cabinets such as dip tanks and spray washers. Under special conditions certain kinds of phosphate coatings can be applied to aluminum, magnesium, tin, titanium and other metals. Many alloys of steel, including stainless steel, can also be phosphated but only with difficulty and by special methods.

Phosphating equipment includes dip tanks, spray washers, tumbling barrels, conveyorized dip mechanisms, stationary spray cabinets and a number of other special devices. Much of the phosphate-bath equipment can be of mild steel, although stainless steel is preferable for dip and reservoir tanks because of longer life and minimization of sludge. (Whether mild steel can be used for tanks depends largely on two things, pH and tank-protecting nature of the bath. Mild steel cannot be used for solutions of low pH. On the other hand, a phosphate bath with a pH greater than 2.0 will phosphate and protect its own tank, although making some extra sludge.)

Characteristics of Phosphate Coatings

As has been brought out in previous articles in *Metal Progress* (see September 1960, p. 101 and April 1961, p. 100), phosphate coatings provide a barrier against corrosion in the form of a protective chemical coating on the surface and also serve as a foundation for paints, varnishes and oils. The phosphate coating must be continuous, adhere well to the surface, and be of a texture suitable for the intended use. In texture and color it must be reasonably uniform so as not to cause blotches and streaks in the paint to be applied over it. The phosphate coating not only affords a considerable measure of protection against corrosion, but also improves the corrosion resistance of organic coatings by holding them more tightly to the surface. This bonding is particularly essential at the edges, over broken parts of the surface, around holes, and in crevices. It is, therefore, highly important to insure a continuous, uniform phosphate coating over every part of the surface. This means that the metal surface must be thoroughly clean and free from rust and loose scale.

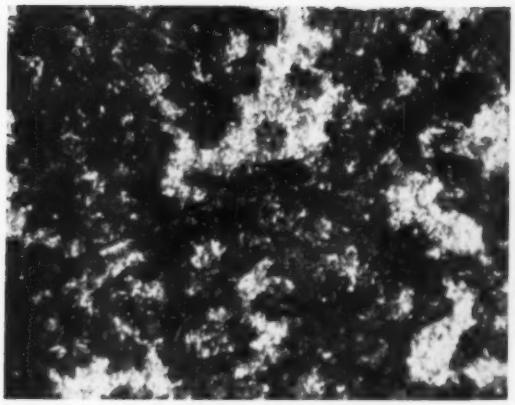
Parts Must Be Clean

Phosphating processes cannot operate through grease or other soil. Hence, all soils must be removed thoroughly so that the cleaned surface will not show a water break when held under cold running water. In the so-called iron-phosphate processes, cleaning is performed simultaneously with phosphating by incorporating surface-active agents and alkali metal phosphates that will promote grease removal. For the zinc and manganese phosphate processes, and in some iron-phosphate installations, it is usually necessary to clean the parts before phosphating.

Another general principle that applies to all phosphating is the necessity of thorough water rinsing between the various stages. In the iron-phosphate processes the work may pass through two successive phosphate stages without rinsing, but for all others there must be good water rinsing between the successive chemical solutions. The water rinses must be kept reasonably pure by constant overflow of the tanks and by frequent complete change, usually once daily. This is particularly true in areas where the water is hard or where the rinse water is subject to any kind of contamination. In some instances, it may be advisable to use demineralized water for final rinsing.

The corrosion resistance provided by phosphate coatings can be enhanced by rinsing the parts in a very dilute chemical solution which is absorbed into the fresh wet coating. Several kinds of solutions may be used for this final rinse, but generally it is one which contains chromate ions. The chemical penetrates the coating and becomes a part of it; it is not rinsed off. For best inhibitive effect the concentration should range up to about 2 lb. of chromic acid or a chromate per 100 gal. of water; however, staining may occur if the concentration is too high. On thick crystalline coatings, staining may be of no consequence; on thin coatings such as iron phosphates, it may be serious. Hence, one must choose between concentrations of 8 oz. to 2 lb. per 100 gal. Temperature of the final inhibitive bath is not significant, but for fast drying, it should be relatively high, although not above 180° F. The pH of inhibitive baths is usually held between 2.0 and 6.0.

It is desirable to dry and paint parts as promptly as possible after phosphating. After coming from the final inhibitive rinse, the work should go immediately into a drying chamber. There should be as little time and space as possible between the final stage and the drying chamber. Moisture that has accumulated in crevices or in any area particularly subject to corrosion should be blown off.



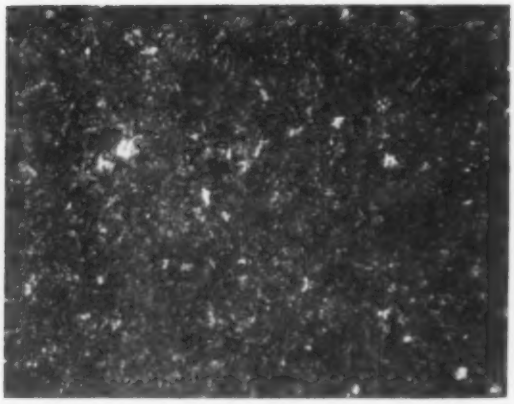


Fig. 1 – Heavy-Duty Cleaner Used on Steel Surface Results in Coarse Phosphate Crystals (Left.) Better coating (right) is formed when a cleaner of low alkalinity is employed. 45 ×

Heavy-Metal Phosphating Baths

Heavy-metal phosphating baths produce coatings which contain zinc or manganese phosphates (or both) and also some iron phosphate, when used on steel. The coatings are much more substantial than the so-called iron phosphates; they consist of layers of metallic phosphate crystals, gray in color, which are soft and easily scratched but quite adherent to the underlying metal. The chemicals for preparing the baths are sold as concentrated liquid solutions of zinc and manganese acid phosphate that also contain chemical accelerators and some free phosphoric acid. Processing baths are prepared by mixing small proportions of the solution with water to form dilute baths which are then heated to the proper operating temperature. Coatings are of considerably better quality than those of the iron phosphate type, being much thicker and of inherently superior corrosion resistance. This type of phosphating is termed "crystalline" in contrast to the designation of "iron" phosphate. The crystalline coatings are usually specified where maximum quality must be achieved.

Five Stages Needed

Because of the nature of crystalline phosphate, these coatings cannot be advantageously produced by baths containing organic surface-active agents. Hence, it is necessary to clean the surface and remove all rust, foreign matter and loose scale before phosphating. Heavy-metal phosphating must, therefore, be performed in an installation having a series of at least five successive stages, which will provide for cleaning, rinsing, phosphating, rinsing, and

Fig. 2 – Jernstedt Activator, Added to the Cleaner or to a Rinse Tank Preceding Phosphating, Greatly Enhances the Smoothness of a Phosphate Coating (Right). Sample on the left was not treated with an activator before being coated. 45 ×

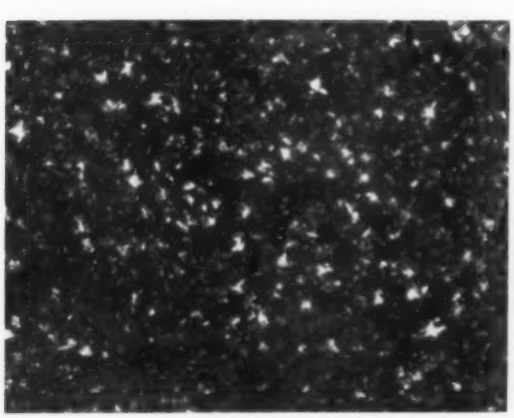


Fig. 3 – Multistage System for Dip Phosphating Usually Consists of Five Tanks for Cleaning, Phosphating and Rinsing

a final inhibitive rinse. Where pickling or other operations are necessary, the number of stages may even be nine or more. Also, multiple rinse tanks may be desired to improve the efficiency of rinsing.

In crystalline phosphating it is highly important to promote formation of dense crystals of small size which are closely packed and uniformly distributed over the surface. The formation of phosphate crystals is unfavorably influenced by many conditions such as harshly alkaline materials in the pre-cleaner. This type of cleaner may remove grease and soil very efficiently, but it imparts a condition to the metal surface which results in relatively large, coarse, blotchy crystals as shown in Fig. 1. On the other hand, the cleaner must effectively remove grease and loose soil.

Activators Improve Coating

Another general principle of heavy-metal phosphating is that of "metal activation". Some 20 years ago, Jernstedt of Westinghouse Electric Co. discovered that the quality of phosphate coatings is greatly improved by small amounts of titanium compounds present in alkaline pre-cleaners or in special dip baths. The exact mechanism of this action is not known, but it promotes the subsequent formation of densely packed, small phosphate crystals, making a better coating than could be obtained without the use of the activator. As shown in Fig 2, smoothness of coating and corrosion resistance are improved and consumption of paint is less.

There are two ways in which to use a Jernstedt activator. For maximum effect it should be made into a very dilute solution of about ½ oz. per gal. of water and used as a pre-dip prior to phosphating. A water rinse is generally recommended between the activator and the phosphating. This pre-dip method is one that is almost indispensable when the steel is pickled. There should be good rinsing after the pickle, then the activator pre-dip and another rinse – applied before the phosphating operation.

Another, somewhat less effective, method of using an activator is to add it to the alkaline pre-cleaning solution. The proportion may range from ½ oz. to 1 oz. per gal., added to the water along with the cleaning compounds. The cleaner bath is then used in the usual way.

Activators have relatively short life and must be frequently renewed or replenished. When work schedules are heavy, it may be advisable to replenish the activator in a cleaning bath every day, even though the cleaning bath is working satisfactorily with regard to grease removal. In pre-dip baths, where the activator

Fig. 4 – Treating Parts So That Large Areas Are Held in Vertical Position Is the Recommended Procedure for Best Phosphating Results. Shown here is some of the equipment at Birtcher Corp., Los Angeles, Calif.

Fig. 5 – In Dip Phosphating, the Volume of the Bath Should Be Large in Relation to the Area of the Work Surfaces. Operation shown here is an open-tank line at Precision Sheet Metal, Inglewood, Calif.

is used alone, it is advisable to renew the bath daily.

Economical Pickling

When rust or lose scale is present on steel surfaces, it must be removed before phosphating by pickling or sand-blasting. The most economical means is by a hot, inhibited acid bath (12% H_2SO_4), which is ordinarily used by dipping for periods ranging from 3 to 10 min. at 150° F. Sometimes, however, phosphoric-acid pickle must be used to comply with certain military specifications. After all of these pickling baths, rinsing must be thorough and should be done with cold water.

Zinc Phosphate Dip Baths

The zinc type is the most widely used heavy-metal phosphate bath, particularly with parts to be painted. The operations must be carried out in an installation with a minimum of five stages. We are concerned here with the dipping application.

After the bath is made up, it must be "broken in"; that is, it must acquire a small amount of dissolved ferrous phosphate. One may simply tolerate a little poor work during the first loads, until some iron has gone into solution, or some sludge left from a pre- *(Continued on p. 116)*

Metal-Metal Oxide Composites for High-Temperature Use

*By KLAUS M. ZWILSKY and NICHOLAS J. GRANT**

Given the same base metal, dispersion-strengthened composites are stronger (at higher temperatures and for longer times) than their counterparts in age-hardenable alloys. The superiority of these materials is the result of increased stability which is attributed to their resistance to recrystallization up to temperatures near the melting point of the base metal. (J27, Q-general; 6-70)

IN THE LAST FEW YEARS, engineers have been combining powdered metals and refractories to produce materials with improved mechanical properties at room and elevated temperatures. Dispersion strengthening, as this technique is called, consists of dispersing a finely divided refractory throughout a metal matrix (generally by powder metallurgy means), followed by deformation (usually through extrusion) of the composite. The finely dispersed phase gives the composite material very high creep resistance and structural stability at high temperatures. Since the metal remains as the continuous phase, properties such as ductility and workability remain metallic in character.

"SAP" Composites Were First

The potential of this strengthening mechanism was first realized in the aluminum-aluminum oxide system. Aluminum forms a very stable, thin, adherent oxide film, the thickness of which can be controlled to 0.01 micron or less on individual particles. These particles can then be consolidated by compacting, sintering and hot extruding to produce mixtures containing a fine well-distributed dispersion of alumina within the aluminum matrix. Such sintered aluminum powder, or "SAP", composites can be produced with 0.5 to 20 vol.% of oxide, thus providing a series of composites which get stronger and become lower in ductility with increasing oxide content.

From the beginning, it was recognized that these materials had high resistance to recrystallization and deformation at elevated temperatures. For instance, in a recent study a SAP composite containing 10 to 14 vol.% alumina attained a hardness of Rockwell F-87 when cold rolled 29%. Annealing for 124 hr. at 1140° F. (615° C.) dropped the hardness only three points, from Rockwell F-87 to 84. Engineers have also proved that SAP has higher stress-to-rupture properties at 900° F. (480° C.) than do the best age-hardened aluminum alloys at 600° F. (315° C.). This superiority is associated with unusual flatness of slope of the curve which relates log stress and log rupture life of the dispersion-hardened alloy, and the absence of structural instabilities which can result in poorer load-carrying capacities over long times.

Applications to Other Systems

Unfortunately, few other metals form the thin oxide coatings typical of aluminum. In submicron powder sizes, many of the engineer-

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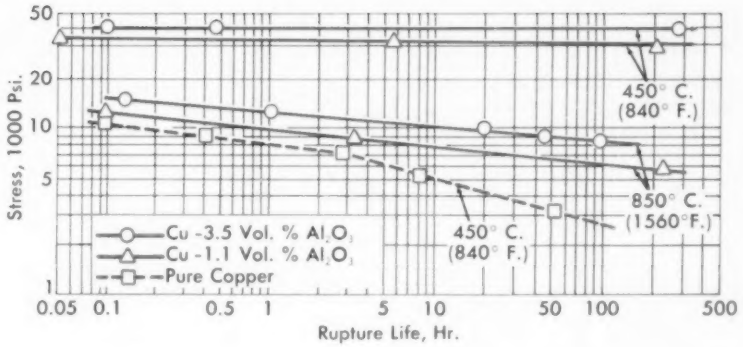


Fig. 1 – Stress-Rupture Properties of Pure Copper and Two Copper - Alumina Composites at Two Temperatures. Note that larger amounts of the dispersed constitutent, alumina, strengthen the composite. The alumina particles inhibit recrystallization of the copper

ing metals are pyrophoric, or develop oxides which are too thick, or yield oxides which are not sufficiently refractory or stable at elevated temperatures. Furthermore, some of the less refractory oxides are quite plastic at extrusion temperatures, and coalesce into rather coarse globules which do not produce dispersion strengthening.

A number of methods have been investigated to disperse a second phase throughout a metal matrix. Of these, the two which are most important are "mechanical mixing" and "internal oxidation". In terms of general usefulness, mechanical mixing has found the widest application because it is a relatively fast, inexpensive method for preparing alloys on a pilot-plant scale. The two powdered phases are mixed in a ball mill or a high-speed blender and heat treated at a low temperature in a reducing atmosphere to eliminate unstable oxides. The blended powder can then be vacuum-compacted and hydrostatically pressed into billet form. Hot working, the last step, is usually carried out by extrusion.

For optimum strengthening, however, the internal oxidation method is superior to any other technique investigated so far. A dilute, metallic solid solution, having as the solute element a metal capable of forming an insoluble, refractory oxide, is exposed to a partial pressure of oxygen for the proper time and temperature. The solute metal then oxidizes to a finely dispersed refractory oxide, leaving the solvent metal or alloy (which is more resistant to oxidation) in a pure form. Composites formed in this manner have a much more uniform structure and finer interparticle spacings than composites made by other methods. In actual demonstrations, alloys formed by this technique have shown levels of high-temperature strength similar to those measured for the SAP alloys, but with considerably smaller quantities of oxide.

Thus far, however, the commercial unavail-

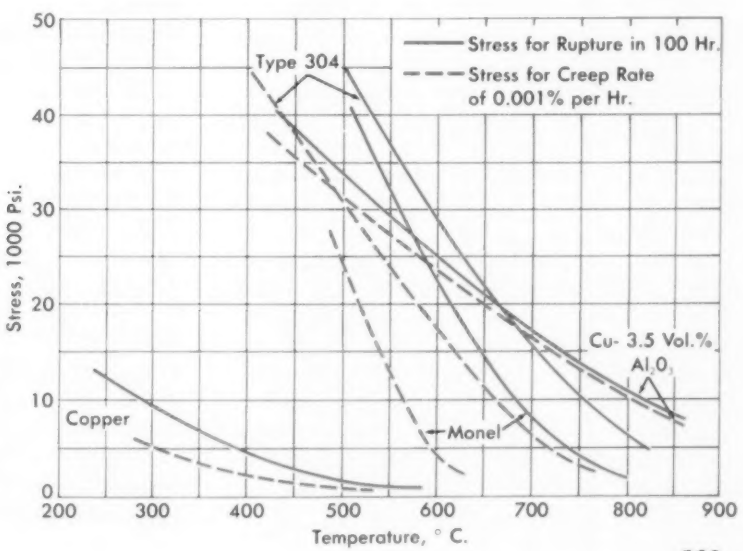


Fig. 2 – Stress-Rupture and Creep Rate Curves for a Copper-Alumina Composite, Pure Copper, Monel, and Type 340 Stainless Steel. Above 1240° F. (670° C.), the composite has the highest rupture strength. It also exhibits a higher stress for a creep rate of 0.001% per hr. above 910° F. (490° C.)

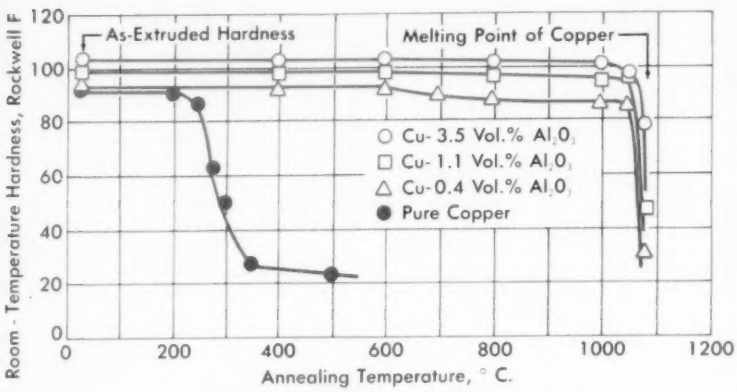


Fig. 3 – Annealing Curves (1 Hr. at Temperature) for Three Copper-Alumina Composites as Extruded and Pure Copper, 50% Cold Worked. Note that recrystallization, which begins at about 400° F. (200° C.) in the pure copper, is inhibited in the composites up to a few degrees below the melting point of copper. The micrograph of the copper-3.5 vol.% alumina annealed at 1975° F. (1080° C.) shows that cold worked and elongated copper grains persist in the areas containing the dispersed alumina particles. Etchant, ammonia plus hydrogen peroxide; 500 ×

ability of fine solid-solution powders and the long exposure times necessary for successful internal oxidation have confined studies to a limited number of alloy systems. Also, this process is inherently more expensive than mechanical mixing or other techniques.

Copper-Aluminum Oxide Composites

Stress-rupture data were obtained at two temperatures for a copper-10 vol.% alumina composite prepared by mechanical mixing. When compared with pure copper (100-hr. rupture life), the copper-alumina composite was 9.5 times as strong at 840° F. or 450° C. (24,800 against 2600 psi.) and 14 times as strong at 1020° F. or 550° C. (17,000 against 1200 psi.). Further, the copper-alumina aggregate exhibited a flat, stable slope without the usual equicohesive break evident in the curves for pure copper. The large increase in the yield strength, from 8000 to 60,500 psi., was accompanied by a decrease of only 35.4% in the conductivity of the copper-alumina composite compared to pure copper.

Figure 1 presents stress-rupture data at 840° F. (450° C.) and 1560° F. (850° C.) for two copper-alumina combinations internally oxidized at 1740° F. (950° C.). The composites contain 3.5 and 1.1 vol.% of alumina (particle sizes: 0.0047 and 0.0083 micron, respectively). At 840° F. (450° C.), the 3.5 vol.% alumina composite has a 100-hr. rupture strength of 38,000 psi., better than 14 times that of pure copper.

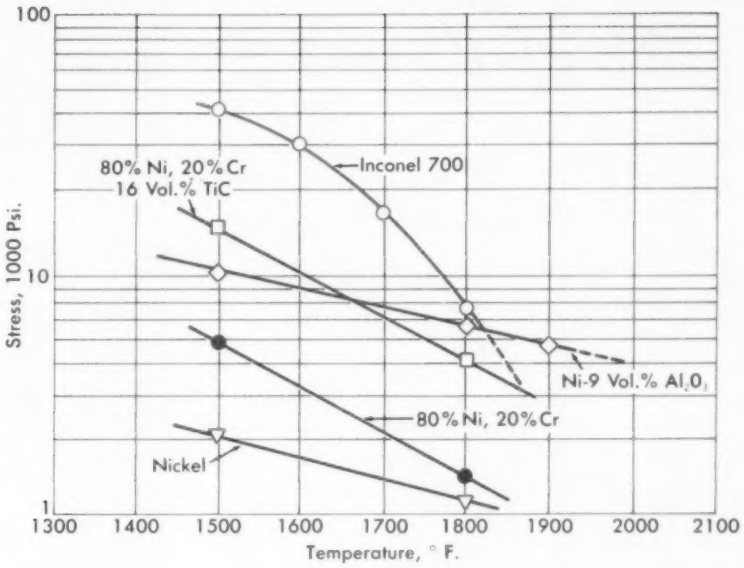
In Fig. 2, the creep and stress-rupture properties of the copper-3.5 vol.% alumina composite are compared to those of Type 304 stainless steel and Monel (70% Ni, 30% Cu.) over the range of 840 to 1560° F. (450 to 850° C.). Above 1240° F. (670° C.), the copper-alumina combination is stronger in terms of the stress to give a 100-hr. rupture life than Type 304, and it is twice as strong as Type 304 at 1560° F. (850° C.). It is also stronger in terms of the stress for a creep rate of 0.001% per hr. above 910° F. (490° C.).

Some explanation for the strengthening effects of the dispersions becomes apparent in Fig. 3 which shows annealing curves for three internally oxidized copper-alumina alloys. The two alloys of higher alumina content show little or no recrystallization to within a few degrees of the melting point of copper, though pure copper recrystallizes in the 480 to 570° F. (250 to 300° C.) range. In line with the hardness data, the micrograph in Fig. 3 reveals that the 3.5 vol.% alloy recrystallized only about 6% when it was annealed for 1 hr. at 1975° F. (1080° C.), a few degrees below the melting point of copper.

Nickel and Molybdenum Composites

Experiments on the mechanical mixing of nickel and nickel-base alloys have also shown improvements in strength properties. Figure 4 compares data for *(a)* nickel-9 vol.% alumina composite; *(b)* pure nickel; *(c)* an 80% Ni, 20% Cr powder with 16 vol.% titanium carbide; *(d)*

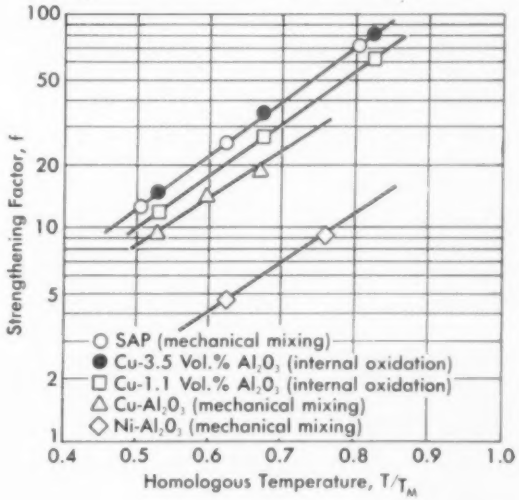
Fig. 4 – Two Nickel-Based Composites Compared With Pure Nickel and Nickel Alloys. Note that the carbide and oxide dispersions have aided the creep-rupture strength considerably



pure 80% Ni, 20% Cr alloy; and *(e)* Inconel 700, one of the strongest wrought nickel-base alloys. The two mechanically mixed composites have from three to five times the strength of their respective metal counterparts. Comparison of the nickel-alumina combination to Inconel 700 shows that the former has higher stress-rupture properties above 1800° F. (980° C.) and is twice as strong at 1900° F. (1040° C.). In contrast, Inconel 700 overages at these temperatures and drops rapidly in strength, while the curve for the nickel-alumina composite maintains its flat, stable slope.

This mechanism of strengthening can also be used with the refractory metals, as experiments with molybdenum have proved. However, difficulties in hot working and fabricating molybdenum-metal oxide alloys from powders have prevented researchers from reaching optimum properties at present. Preliminary experiments have indicated that considerable strengthening can be obtained with minor additions of hard, refractory oxides having a high negative free energy of formation, such as Al_2O_3, Cr_2O_3, ZrO_2, and TiO_2. While pure molybdenum tested in vacuum at 1800° F. (980° C.) at a stress of 25,000 psi. fails in about 5 hr., oxide additions of 0.1 to 2.0% have produced time-to-rupture values varying from 300 to 600 hr. The arc-cast molybdenum alloys are still better, however. Molybdenum plus 0.45% Ti is one of the best of them; it has a 100-hr. rupture strength of 40,000 psi. (compared to the 24,000 psi. for the molybdenum-zirconia composite). However, by using the optimum oxide content and fabrication techniques, it should be possible to equal or exceed the rupture strength properties of the better arc-cast molybdenum alloys. Recent experiments have demonstrated that internal oxidation can increase the high-temperature strength of 0.5% Ti molybdenum alloys by 20% and 1.5% Ti *(Continued on p. 122)*

Fig. 5 – Five Dispersion-Hardened Composites Rated According to Homologous Temperatures, T/T_m, Where T Is the Test Temperature and T_m Is the Melting Temperature of the Base Metal, Both in Absolute Degrees. Strengthening factor, f, is the ratio of 100-hr. rupture stress of the dispersion-hardened composite to that of the pure base metal



Short Runs

Electrostatic Painting of Refrigerators

TO MODERNIZE ITS FINISHING FACILITIES at Grand Rapids, Mich., Kelvinator Div. of American Motors has installed an automatic system for painting refrigerator cabinets and doors. The installation employs 33 Ransburg electrostatic painting units and replaces a battery of hand spray and automatic air guns.

The new painting line applies a uniform coating of paint 1.8 to 1.9 mils thick on all parts, regardless of size. Kelvinator produces four basic refrigerators ranging in size from 64 by 41 by 24 in. to the smallest model which measures 36 by 24 by 24 in. With the new equipment, the company has achieved lower production costs and better quality. Rejects have been virtually eliminated and there have been substantial savings in paint.

The changeover to electrostatic painting was made during a three-week vacation shutdown and required major remodeling. Five water-wash spray booths were removed; a new indexing system and more ventilation equipment were installed. Workholder centers were enlarged to accommodate a variety of models and sizes. A circulating line from the paint-mix building supplies enamel to a 55-gal. drum in the paint room, and a separate circulating system takes it from the drum, through heaters and filters, to the electrostatic units. The installation is enclosed in a pressurized room with temperature maintained at 80° F.

After fabrication, refrigerator cabinet shells and doors are hung on an overhead line for cleaning. The work goes through a six-stage phosphating line which includes cleaning, a hot-water rinse (140 to 150° F.), a cold rinse, phosphate application at 160° F., another cold-water rinse and, finally, a rinse in deionized water. The work is then transferred from the overhead line to a 1260-ft. long floor conveyor operating at speeds from 12 to 24 ft. per min.

Sides of cabinet shells and doors are painted at the first electrostatic station (Fig. 1) consisting of four reciprocating units, two on each side of the line. Each unit has three atomizing bells, mounted one above the other. The 4-in. bells, rotating at 900 rpm., move up and down on a short stroke to apply a uniform coating of paint electrostatically. As parts of different sizes move in front of painting units, the bells (controlled by limit switches) move away from or toward the work to maintain proper painting distance. Paint is triggered on and off automatically by photoelectric cells.

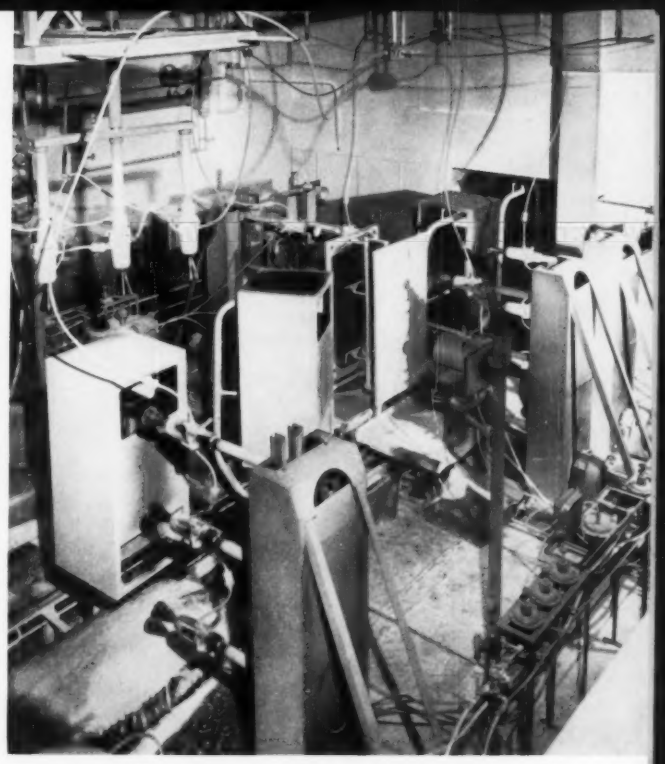


Fig. 1 — Ransburg Moving-Bell Atomizers Automatically Paint Refrigerator Cabinets and Doors on Kelvinator's Finishing Line. Electric eyes selectively trigger the paint on and off between parts, and limit switches re-position the electrostatic painting units to accommodate different sizes

As the cabinets move toward the second station, they are turned by an indexing system. Backs of cabinets are painted with a three-bell reciprocating unit as another painting unit, mounted overhead, applies the first coat to cabinet tops.

After a short flash-off, the bells are automatically triggered for another application of paint to cabinet tops. Cabinets are indexed back to their original position before entering the final electrostatic station for a second coating on the sides.

After being painted, cabinet shells and doors move into a gas-fired oven to bake at 305° F. for 30 min., and are then transferred to the production line for final assembly.

MEMO

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SUBJECT– *Precleaning eliminated*

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LETTERS TO THE EDITOR

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More About Bells

OTTAWA, ONT.

Harold Roast's article on Big Ben ("A Century-Old Test of Metal", *Metal Progress*, December 1960, p. 99) triggered some memories of Riga High School (around 1911) and the painful memorization of a 425-line, 160-year old poem by Schiller, "Das Lied von der Glocke" ("The Song of the Bell")*.

Schiller seems to have been a very good observer (for a poet!): He mentions, among other things, a clay mold, specially dried; alloying of copper with tin; fluidity of alloy; degassing; adding of potash; poling; judging of temperature by color; sampling; fracturing sample and observing dendrites; master's orders for tapping; casting; "fire-brown" stream; risk of mold bursting (due to hydraulic pressure); slow cooling; removing mold material; christening the bell "Concordia", hanging it up and tone testing.

Another bell then came to mind — a "walk-in" type, displayed on a pedestal in Moscow. (I stepped into it in 1916 and it was the size of a log cabin.) I do not recall whether it cracked after hanging or for another reason, but a door-size chunk was missing and visitors walked in and out. Anyway, this one was not as good as the Big Ben.

*Published by D. C. Heath & Co.

R. PUTNAERGLIS
Associate Professor of Engineering
Carleton University

"Hypereutectic" or "Hypoeutectic"?

READING, PA.

Your June 1961 issue contains an article by Peter Payson, titled "High Speed Steels Meet Tool Needs — I". In the article, high speed steel is referred to as a hypereutectic steel. We feel there has been an error in describing the steel in this manner.

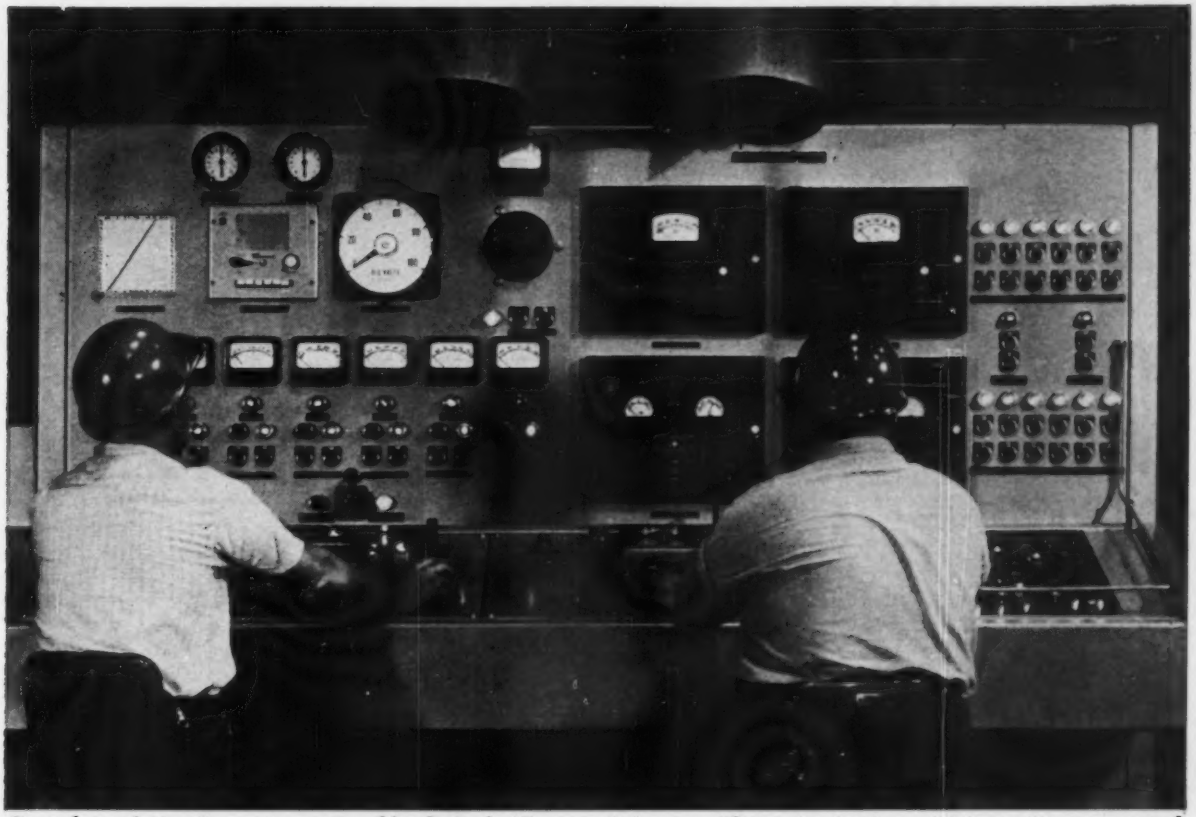
The most widely accepted data on the freezing of high speed steel is K. Kuo's article in the *Journal* of the Iron and Steel Institute, Vol. 181, 1955. As can be seen in his quasibinary diagram, a hypereutectic high speed steel would necessitate much greater than 2% carbon. Basic knowledge of the microstructure of cast high speed steel indicates that the steel is not hypereutectic. To be hypereutectic, primary crystals of carbide would have to be present in the microstructure. The fact that austenite and carbides are present up to the solidus, an argument Mr. Payson employed, does not necessitate that the steel be either hypereutectic or hypereutectoid, since in this complex alloy system the hypoeutectoid region contains several phases, carbide being present up to the solidus.

JAMES R. OBERHOLTZER
Assistant Metallurgist
Tool & Alloy Research
Carpenter Steel Co.

AUTHOR'S REPLY — In reference to Mr. Oberholtzer's comments concerning my article, I already have had a discussion with some of my associates on my unfortunate selection of the term "hypereutectic" to describe the structure of high speed steels. I have been convinced this was an error. Unfortunately, this discussion was held after the article had gone to print.

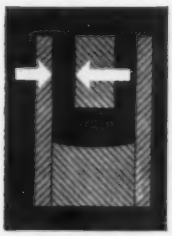
I now believe it is best to avoid trying to classify so complex a system as a high speed steel composition in the terms that are useful for the simple binary systems. For the high speed and high-carbon, high-chromium steels, I believe it is sufficient to state that the steels consist of austenite and residual carbides right up to the solidus temperatures.

PETER PAYSON



Control panel of a Carpenter consumable electrode (Consumet) furnace. Electronic circuits maintain positive arc control and precise electrode movement to assure the ultimate in refining.

Where *Carpenter's* "big inch" makes a mile of difference in alloy quality



The "big inch" in Carpenter's consumable electrode (Consumet®) furnace is the extra space between the consumable electrode and the mold wall. (Conventional furnaces of this type are almost ⅓ smaller at this vital point.) The "big inch" in Carpenter's furnace provides more exhaust space to carry off harmful gases. It also gives Carpenter technicians more precise vacuum control during the arc strike as well as during the entire melting process. As a result, you get cleaner, more uniform alloys from core to surface. Segregation and variation in grain size are minimized . . . to assure you consistent, predictable performance from your vacuum melted alloys. The "big inch" is only one of many exclusive Carpenter quality controls in consumable electrode, MEL-TROL® and vacuum-induction-melted (VacuMeltrol®) specialty steels. Ask your Carpenter representative for the full story behind these alloys and how they benefit you.

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Phosphating . . .

(Continued from p. 107)

vious bath or crusted on the side of the tank may supply the desired trace of iron. Frequently, a new steel tank will impart enough dissolved iron to the bath. One may either suspend some cleaned steel wool in the fresh bath, or clean up some scrap iron and immerse it for a short time, or introduce a little clean iron powder. Another method is to add 6 oz. of ferrous iron phosphate to each 100 gal. of bath.

If sodium nitrite is to be used as an accelerator, it should be added with whatever is used for break-in. The bath should now have a somewhat milky appearance and be ready for operation.

Operating Dip Baths

During dip phosphating, all significant surfaces should be in a vertical position and openings to interior surfaces should be provided. The workpieces should not touch each other, should be above the bed of sludge, at least 2 in. below the surface of the liquid and well away from sides of the tank. Best results are obtained when the volume of the bath is large in relation to the total mass of work surfaces. Preferred immersion periods and working temperatures are called out in the instructions supplied with the phosphating chemicals, but sometimes these must be varied somewhat according to circumstances. Most of the coating will go on within the first minute or so; however, it will usually be thicker and of better quality the longer the work remains in the bath.

Other Dipping Methods

There are a few modifications of the simple dip procedure. For example, parts may be carried through the tanks on conveyors. With this arrangement, speed of the conveyor and the length of the tanks are important factors which need to be considered to insure adequate processing time.

Another variation is that of the tumbling barrel, a unit chiefly used with small parts in mass production. Parts are loaded into tumbling barrels with the load usually occupying about one third of the volume. The tumbling barrels are

How to braze 28 parts of one assembly at one time

The objects shown above are the individual parts and the final brazed assembly of a solid copper, vapor-cooled anode used in a 400 kw continuous output triode. It's produced by the Machlett Laboratories, Springdale, Conn. There are 28 parts in all and the assembled unit weighs 85 lbs. A total of 51 areas and 20 feet of surface must be brazed in one operation. Strong, uniform, vacuum-tight joints are essential.

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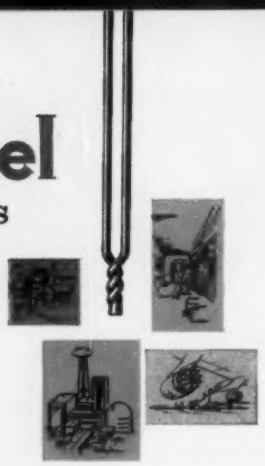

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Circle 777 on Page 48-B

Phosphating . . .

conveyed from one stage to the next and are suspended and rotated at about 4 rpm. within each bath. After the barrels have passed through all stages of the phosphating installation, their loads are usually dumped into a centrifuge in which the liquid is whirled off. Ordinarily, any further drying by hot air is not required because the parts are usually warm and can be dried quite well by the centrifugal action. During phosphating, the parts are, of course, jostled against each other. Sharp corners and edges gouge into the coating already formed, but the scratches are subsequently healed by more phosphating. There is usually an adequate coating although the finished parts are covered with superficial lines and scars. After drying, the parts may then be placed in other tumbling barrels to be oiled or coated with various organic products.

Maintaining Dip Baths

Testing and adjustment should be done frequently enough to insure that correct operating conditions are always maintained. A typical phosphating solution may contain as little as 1.4% of actual phosphating substance and a portion of this must go into every square inch of coating. Hence, phosphate baths must be frequently replenished. Large bath volume in relation to the surface area of the work is the best combination; conversely, if the surface area to be treated is large and the bath small, then the phosphating substance will be rapidly consumed and the bath will grow weak.

It is necessary to add water to the bath to maintain the original working level, and to clean out sludge with reasonable frequency, depending upon how heavily the bath is being worked. Formation of a bed of soft sludge on the bottom of the tank and a hard crust over the heating units and sides of the tank, being unavoidable, are normal features of zinc phosphate baths. Ordinarily the sludge will not cause undue inconvenience provided it is cleaned from the bottom and sides from time to time and knocked off the heating units. However, because sludge is present, baths of this type can not be agitated. It is true that

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Circle 778 on Page 48-B

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SOLUTION...

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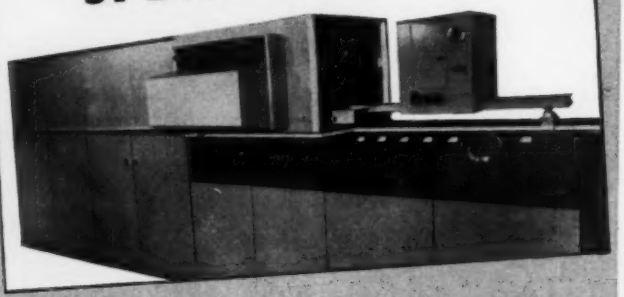

You can speed routine analyses photoelectrically, and still solve tough "odd sample" or research problems photographically—all with the same versatile instrument. No attachments to mount . . . no tedious realignment. With the turn of a single control you can convert from full-range spectrographic analysis to high speed direct-reading analysis of as many as 20 elements simultaneously.

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Jarrell—Ash

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Circle 779 on Page 48-B

Phosphating . . .

spray baths are considerably agitated, but the agitation is not from the bottom and the liquid is passed through screens which keep much of the sludge away from the nozzles.

Management of Ferrous Iron

The zinc-phosphate bath, with no other heavy metal present, produces crystals which are very light gray in color and rather transparent when viewed under the microscope. Zinc phosphate is more corrosion resistant than iron phosphate, but the zinc phosphate crystal is less adherent to the surface. For this reason, zinc phosphate alone is not ideal; it should be supplemented by another heavy metal, such as nickel or iron, that becomes mingled with it. This, of course, occurs readily when the bath is working on steel; a little iron is dissolved continually from the steel surface and deposits with the zinc phosphate crystal. As a result, the coating becomes darker in color, more opaque, and more adherent to the surface. As the iron content builds up, the coating tends to become thicker, darker, more porous and softer. Should the iron buildup continue unduly, harmful effects such as colored blotches, loose powder and "sparkle" occur. If thin, smooth, tight coatings are desired as a base for paint, only a small amount of iron, (about 0.1 to 0.15% of the bath) should be permitted. This is regulated by the proper use of oxidizing "accelerator" agents. On the other hand, for thick, rather porous coatings, the ferrous iron content is allowed to build up to a relatively high level—about 0.25 to 0.4%, calculated on the total weight of the bath.

Coating Zinc and Cadmium

Zinc-phosphate baths can also be used to coat galvanized and cadmium-plated surfaces. The general principles are much the same, but there are some special considerations. For one thing, iron cannot be picked up from the surface except at cut edges. Should the work loads be such that some iron surfaces are included along with the galvanized pieces, then the problem is solved. Otherwise, it may be advisable to introduce steel wool, scrap iron, or to provide a certain amount

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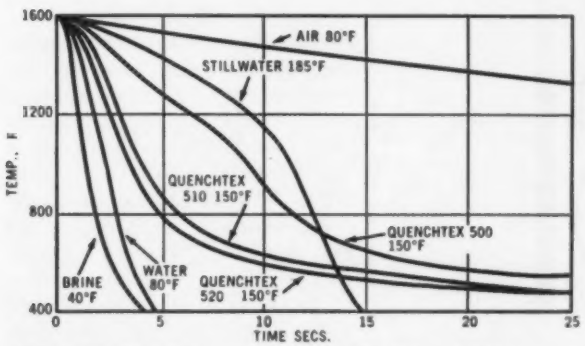

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MT-91

Circle 780 on Page 48-B

PANORAM-X

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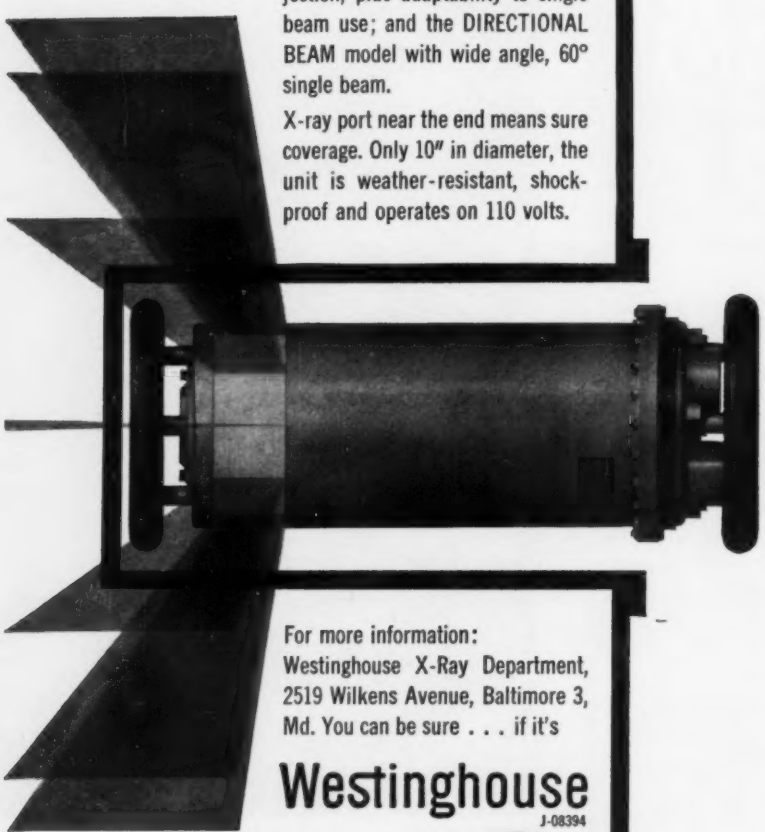

For more information: Westinghouse X-Ray Department, 2519 Wilkens Avenue, Baltimore 3, Md. You can be sure . . . if it's

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J-08394

Circle 781 on Page 48-B

Phosphating . . .

of iron compound to the bath. Another expedient, which is more common, is to supply a fairly generous proportion of nickel phosphate. (Nickel has somewhat the same effect as iron.)

An example of an especially difficult surface is that of hot-dipped zinc. Spangles must be covered uniformly, and, furthermore, galvanized surfaces from different mills will differ considerably as to spangle and other surface characteristics. To meet these difficulties, one must sometimes resort to special agents such as fluorides (about 0.1% of the bath) not ordinarily found in the other heavy-metal phosphates. Electrolytic zinc and cadmium plate do not present any difficulties.

These comments have dealt with some of the necessary features of phosphating systems and with operating techniques for zinc phosphate dip baths. Next month, zinc-phosphate spray systems and methods for applying another heavy-metal coating, manganese phosphate, will be dealt with in a similar manner. A third part, to appear in the November issue of *Metal Progress*, will explore some of the recommended operating practices for "iron" phosphate coatings.

Composites . . .

(*Continued from p. 111*)

molybdenum alloys by as much as 250%.

The plot in Fig. 5 on p. 111 compares the relative strengthening obtained in several alloy systems at elevated temperatures. The strengthening factor, "f", is defined as the ratio of the 100-hr. rupture stress for the dispersion-hardened alloy to the 100-hr. rupture stress for the pure base metal. For a given homologous temperature (the ratio of test temperature to the melting point of the base metal, both in absolute degrees), the largest degree of strengthening obtained so far is for SAP and the internally oxidized copper-alumina alloys. They are followed by the mechanically mixed copper-alumina alloys. In each alloy system, the degree of strengthening can be related to the fineness of the dispersion. Interparticle spacings have been reported to be 0.35 micron for

Diesel locomotive crankshafts, each weighing nearly 3000 pounds, being heated for upsetting the end flange at Park Drop Forge Company.

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Circle 782 on Page 48-B

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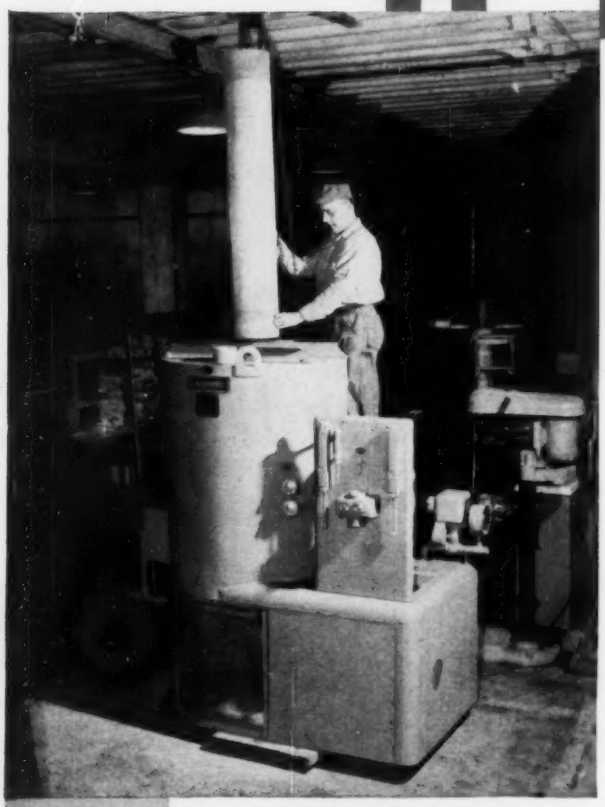

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Circle 783 on Page 48-S

Composites . . .

SAP, 0.3 micron or less for internally oxidized copper-alumina alloys, and 2 to 10 microns in the mechanically mixed alloys. Finer dispersions were obtained in mechanically mixed copper-alumina alloys than in nickel-alumina alloys because of the finer size of the metal powders used (1 micron for copper particles against 5 microns for nickel particles).

It should be remembered that the relative degree of strengthening obtained for each alloy system is also dependent on the purity and, therefore, the relative strength of the base metal used for comparison. For instance, the 100-hr. rupture stress at high homologous temperatures for pure aluminum, copper and nickel is quite low (less than 600 psi.), and a change of only 100 psi. can thus have a significant effect on the strengthening factor, "f".

Potential Applications

For dispersion-hardened composites, "high-temperature strength" is a relative term, the meaning of which depends on the metal or alloy system involved. For example, an increase in operating temperature of from 300 to 600° F. for aluminum or copper-base metals certainly makes a composite superior to any conventional solid-solution or age-hardened alloy. Since other desirable properties, such as corrosion resistance, specific gravity, thermal and electrical conductivity, remain essentially the same, use for these composites can be envisioned for many applications which require greater resistance to high-temperature deformation.

In addition, if dispersion strengthening would allow nickel or refractory metals to be used at temperatures above those at which present alloys lose their strength rapidly, the way would be opened to still other applications. So far, data have been gathered on metals with lower melting points, and research and development has attempted to define the processing and structural variables involved. The effort to translate these results to the refractory metals, though begun only recently, can be expected to show the true potential of dispersion-hardened structures for ultrahigh-temperature applications in the future.

Another Test System at work...

J. E. Rambo, (center) Magnaflux Field Engineer discusses test operations with Chief Metallurgist S. W. Gearhart, and Operator Richard Erich, Birdsboro Corporation, Birdsboro, Pa.

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Circle 784 on page 48-B

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Stuart T. Ross

STUART T. Ross has been named vice-president of research and engineering at Brooks & Perkins, Inc., Detroit.

A graduate of Purdue University (with a B.S. and M.S. degree in metallurgical engineering and a Ph.D.), he comes to the company from the Aeronutronic Div. of Ford Motor Co., where he directed research and development related to applications of light-weight, high-strength and high-temperature materials to weapon and aerospace system requirements and manufacturing methods.

His background in industry includes several years as assistant chief metallurgist at the Harrison Radiator Div., General Motors Corp., Lockport, N.Y., working on the J-65 aircraft gas turbine engine program as high-temperature materials and processing consultant. In 1953 he joined Chrysler Corp.'s engineering division in Detroit and four years later was named manager of the metallurgical research department, holding this post until he left the company two years later.

Active in many technical groups, he was chairman of the A.S.T.M. committee on the electron metallography of metals in 1957-58 and secretary prior to that.

Ardrey M. Bounds

Among the new national officers elected by the American Society for Testing Materials at its recent annual meeting in Atlantic City, N. J., were ARDREY M. BOUNDS and BRUCE W. GONSER, both new members of the board of directors elected for three-year terms.

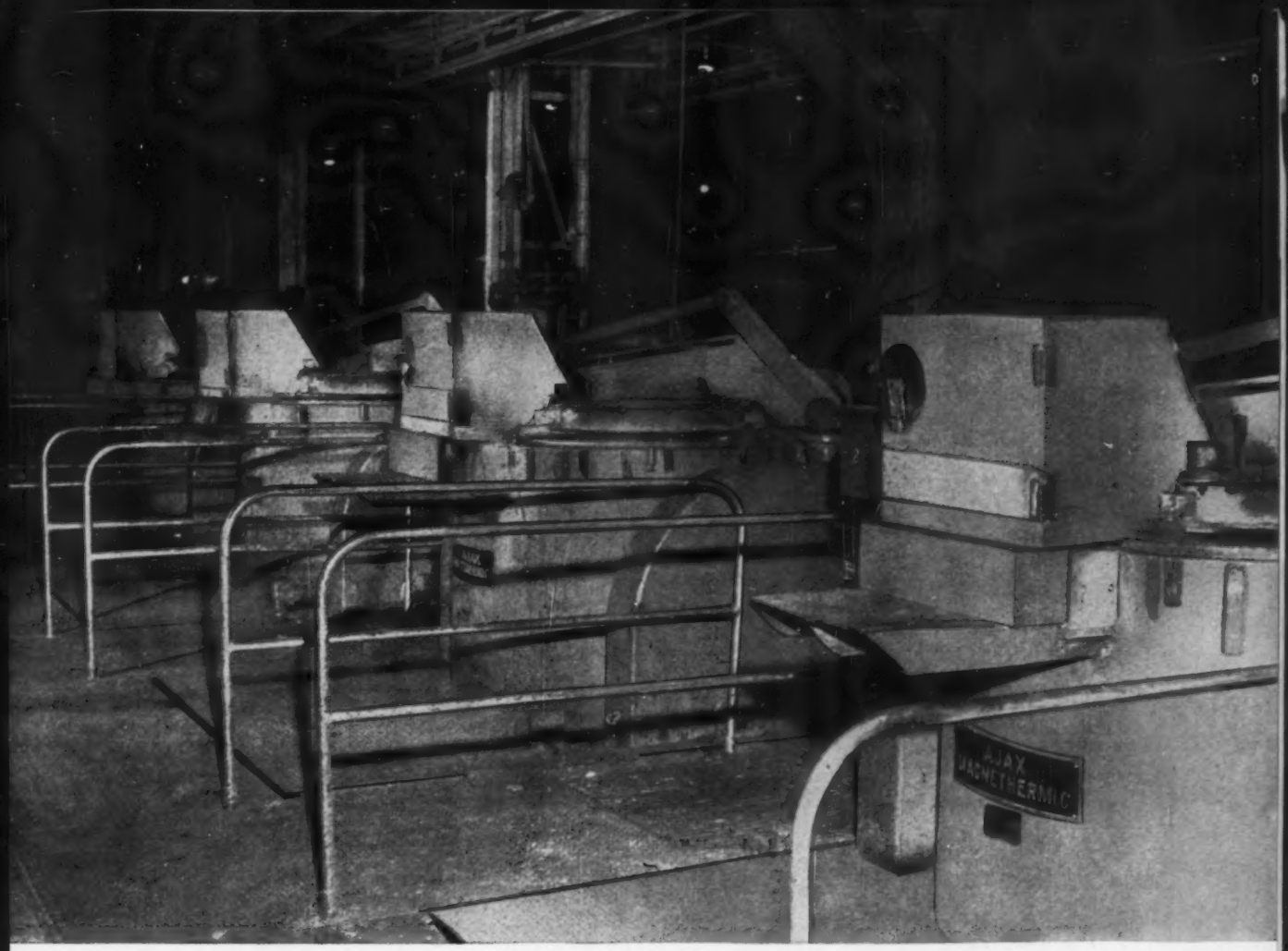
As chief metallurgist for Superior Tube Co., Norristown, Pa., Mr. Bounds is in charge of laboratories and technical services, including production metallurgy, development metallurgy, chemistry and electronics laboratory as well as sections devoted to technical service, raw materials and welding. Graduating from Lehigh University with a B. S. in metallurgical engineering in 1933 and an M.S. in 1936, he joined Superior shortly after its organization and has spent the past 25 years in the tubing industry. His work at Superior has included the theoretical and practical aspects of the function of the base metal in thermionic emission from indirectly heated cathodes, and extensive studies on fabrication techniques for the reactive metals.

He is busy on several A.S.T.M. committees and in addition is past chairman of the Philadelphia Chapter. He was instrumental in setting up the first Junior A.S.M. activity and has been a member of several A.S.M. national committees.

Bruce W. Gonser

Bruce W. Gonser, technical director at Battelle Memorial Institute, began his career in metallurgy after graduating from Purdue University in 1923 with a degree in chemical engineering. He served as a research fellow for a year at the University of Utah, completing his requirements for a M.S. degree in metallurgy. He gained broad experience in varied extractive metallurgy operations in the West as a metallurgist and chemical engineer with the American Smelting and Refining Co., then returned to his studies, receiving his doctorate in nonferrous metallurgy and metallography from Harvard University. Since joining Battelle in 1934, he has initiated studies on the properties and development of uses of such metals as titanium, molybdenum, columbium – and many others. He was among the first to begin research on deposition and coating of metals by the decomposition of vaporized metal halides.

Active in A.S.T.M. since 1936, he has served on several committees including Committee B-2 on Nonferrous Metals and alloys – he was chairman from 1948 to 1960. He is also on the roster of many other technical groups.



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Circle 785 on Page 48-B

BETHLEHEM STEEL COMPANY PHOTO

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Personals . . .

V. B. Cassilly – from salesman in the Jacksonville, Fla., office of Air Reduction Sales Co. to assistant manager, sales, for the Tampa, Fla., district.

James M. Kennedy, Jr. – from chief engineer of the Rome (N.Y.) Div., Revere Copper and Brass Inc., to assistant chief engineer in Revere's executive offices in New York.

Rupert Myers, head of the School of Metallurgy and dean of the Faculty of Applied Science in the University of New South Wales, Sydney, Australia – has relinquished his deanship to serve as pro-vice-chancellor of the University.

William H. Dalman – from assistant treasurer to treasurer of Strategic Materials Corp., New York.

Ernst M. Goldstein – from Metal and Thermit Corp. to the research and development department of Shieldalloy Corp., Newfield, N.J.

Rudolph Smith – from works manager of the Pueblo, Colo., plant of Colorado Fuel and Iron Corp. to executive vice-president, operations.

Howard Biers, consultant to the United Carbide International Co. – elected an honorary vice-president of the Iron and Steel Institute in London. He is the Institute's first American honorary vice-president since the death in 1943 of James Farrell, president of U. S. Steel Corp.

Herman C. Ihsen – retired from the North American Aviation, Inc. Missile Div. after 11½ years as design consultant on materials.

Robert S. Miltenberger – now manager, technical development, at Great Lakes Steel Corp., Ecorse, Mich.

Orlan W. Boston, professor emeritus of mechanical and production engineering at the University of Michigan – received a certificate of appreciation from the American Society of Mechanical Engineers during the Society's annual Design Engineering Conference, in recognition of his work on ASA Sectional Committee B5, devoted to developing standards in the field of small tools and machine tool elements.

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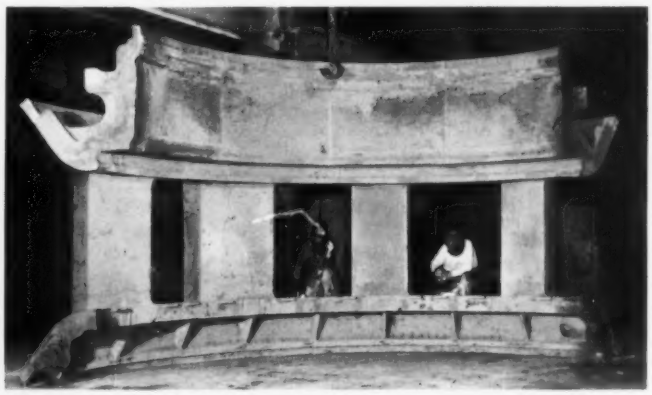

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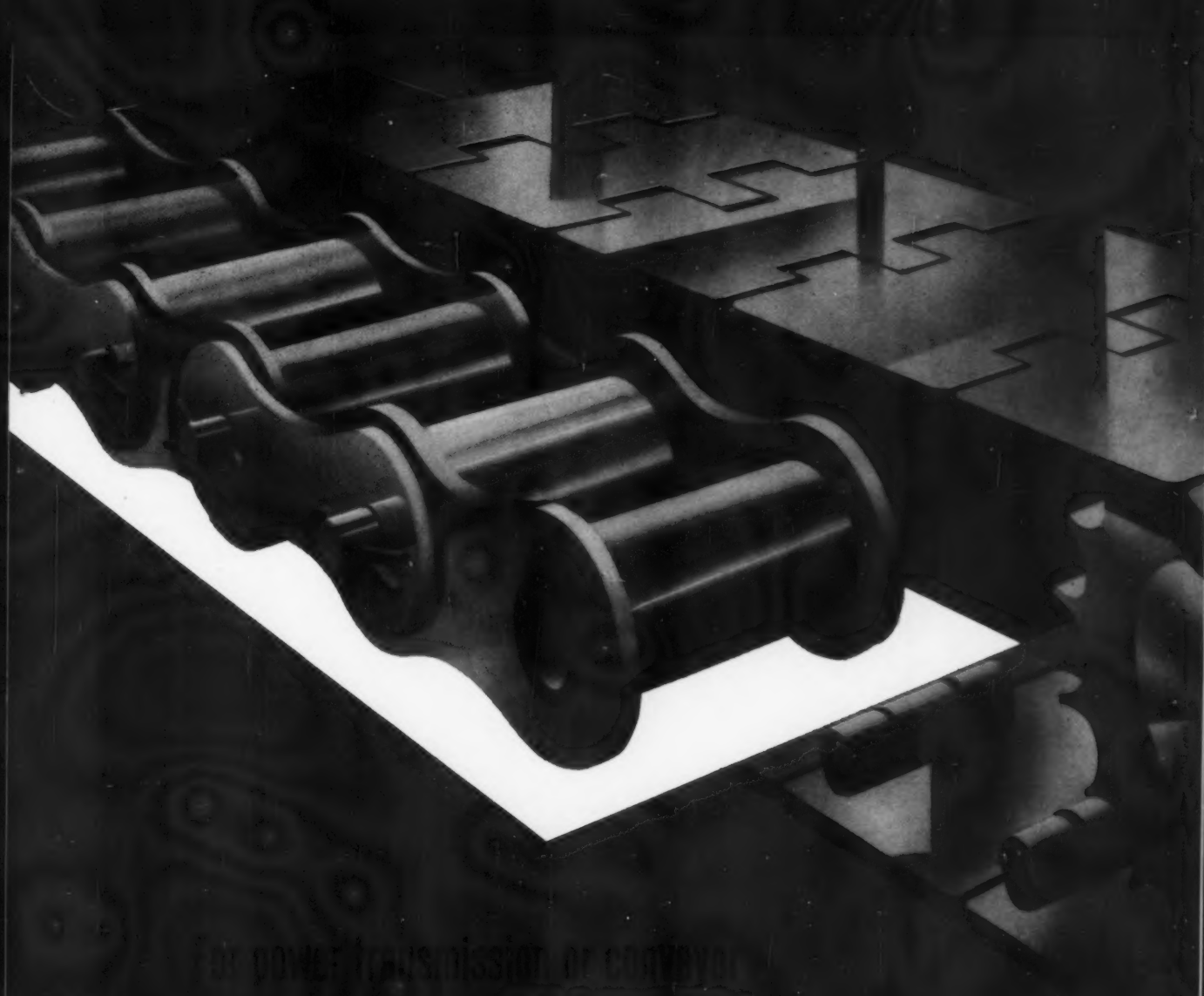

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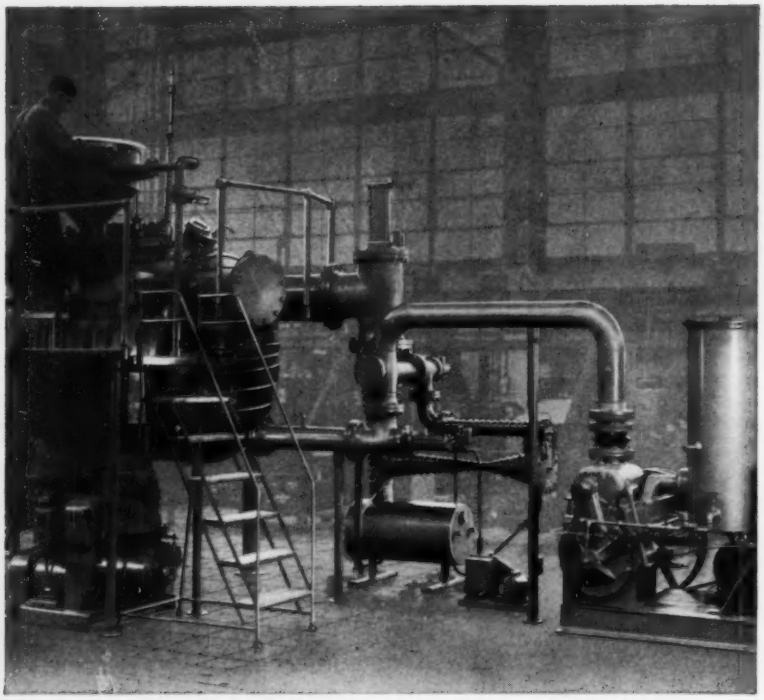
Circle 787 on Page 48-B



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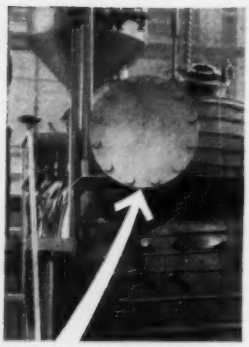

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Personals . . .

Charles L. Harper, manager of the metals division of H. M. Harper Co., Morton Grove, Ill. – elected a member of the board of directors.

Hugh McIntyre – now engineer on the sales staff of the Duraloy Co., Scottdale, Pa., working out of the Detroit office. At the same time, **Robert E. Kroc** was named sales engineer in the Chicago office.

F. R. Hensel – retired as vice-president, engineering, for P. R. Mallory & Co., Inc., Indianapolis, after 26 years with the company.

Stephen A. Fronek – from staff assistant to the director of technology at Crucible Steel Co. of America, Pittsburgh, to product sales manager of silicon steels.

Robert D. Wylie – from manager of quality control for the boiler division of the Babcock and Wilcox Co., Akron, Ohio, to director of the department of materials engineering of Southwest Research Institute, San Antonio, Tex.

Kenneth A. Matticks – from manager, technical service, for Crucible Steel Co. of America, to product manager, stainless flat products.

Andrew S. Macalaster – now president of Macalaster Bicknell Corp., the successor to Macalaster Bicknell Co., Cambridge, Mass.

Charles H. Harton – from district manager, Cleveland, for Carpenter Steel Co., Reading, Pa., to Florida manager.

Harry Osborn, research director of the Tocco Div., Ohio Crankshaft Co., Cleveland – named A.S.T.M. representative on the Council of the American Assoc. for the Advancement of Science.

Peter Payson, assistant director of research, Crucible Steel Co. of America, Pittsburgh – received an honorary doctor of engineering degree from Stevens Institute of Technology, Hoboken, N.J.

John W. Hammarberg – from district representative in the Detroit sales office of Heppenstall Co. and Midvale-Heppenstall Co. to manager of the Chicago sales office in La Grange, Ill.

How to get high alloy performance at low alloy cost

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Nucleonics in Flight

*Reported by W. J. HENDRY and WALTER J. KOSHUBA**

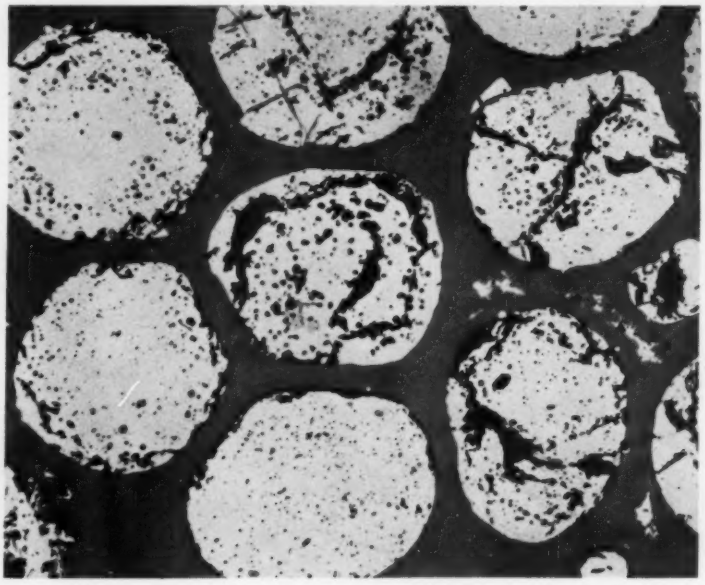
The Aircraft Nuclear Propulsion Program, now terminated, has contributed substantially to high-temperature metals and nuclear technology – such as ceramic-coated fuel particles for improved oxidation resistance – and will continue to contribute much more as additional data is declassified. This report of a recent symposium on Nucleonics in Flight discusses the manufacture of various fuel elements designed to be a part of reactors for nuclear-powered aircraft and space vehicles.

OF PARTICULAR INTEREST to reactor design engineers, metallurgists and physicists, this meeting covered topics ranging from fuels, shielding, heat transfer and radiation damage to reactor safety and controls. The higher temperatures required in reactors for flight propulsion restrict the use of metals, but reactor structural members, moderators and control rods – made of metals – continue to be of interest to nuclear engineers.

Fuel Elements for Flight

Fuel elements in a flight system will generate temperatures in excess of 3000° F. Most available metals – with the exception of refractory elements such as tungsten, molybdenum, and columbium – appear to be eliminated for the application. A presentation by B. W. Dunnington of Battelle Memorial Institute, Columbus, Ohio, was an excellent summary of the unclassified informa-

Fig. 1 – Microstructure of Alumina-Coated UO_2 Particles, Pressure-Bonded. Dark gray material is alumina; white areas are urania particles. The black areas are fissures in the particles. 100 ×



*Mr. Hendry is supervisor, process engineering, and Mr. Koshuba is manager, technical production, Aircraft Nuclear Propulsion Dept., General Electric Co., Cincinnati, Ohio. The Nucleonics in Flight Symposium, held in Dallas, Tex., in March 1961, was sponsored by the North Texas Section of the American Nuclear Society.

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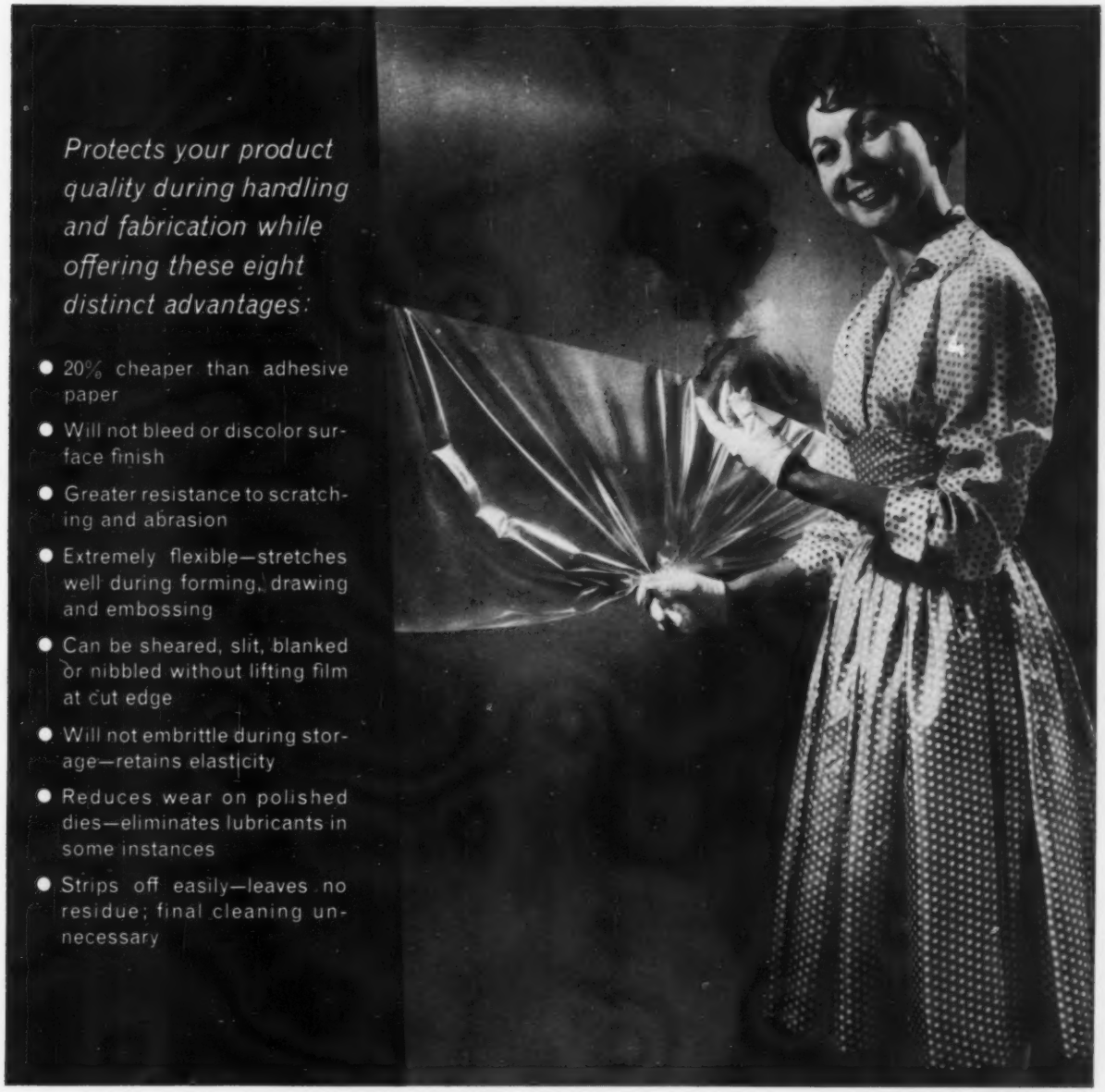

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Circle 790 on Page 48-B

tion available in this field.

Fuels for reactors designed for direct-cycle jet or ramjet systems (to be used in the atmosphere) must be capable of operating in an oxidizing environment at high temperatures. Data from the HTRE (heat transfer reactor experiment) tests which General Electric conducted show that substantial progress on materials for this application has been made. In these experiments, fuel elements of clad UO_2 powder dispersions in 80 Ni, 20 Cr were operated successfully for up to 100 hr. at 1750° F. and for over 100 hr. at 1900° F. in a direct-cycle, air-cooled reactor. An impressive performance, it demonstrates that reactors of this kind are possible.

Use of this fuel element at substantially higher operating temperatures would present problems resulting from lower creep strength, rapid mobility of fission products, and rapid oxidation of the cladding.

Substitution of a refractory metal for 80 Ni, 20 Cr (Nichrome) might be feasible provided a coating is found to protect it from oxidation.

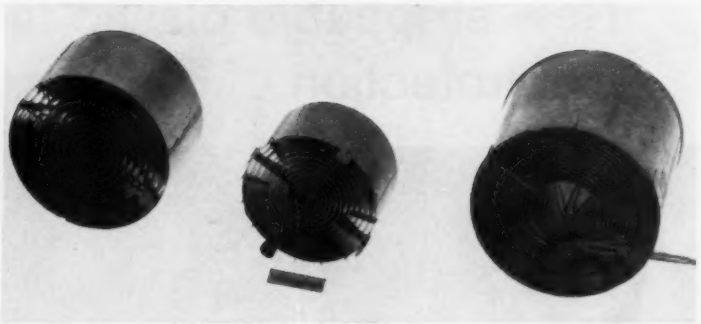


Fig. 2 – Photograph of HTRE (Heat Transfer Reactor Experiment) Fuel Elements. HTRE-I element is on the left and HTRE-III is in the center. The element on the right is an advanced design, 3 in. long, which has a center opening for the moderator. Instrumentation is also shown on this element

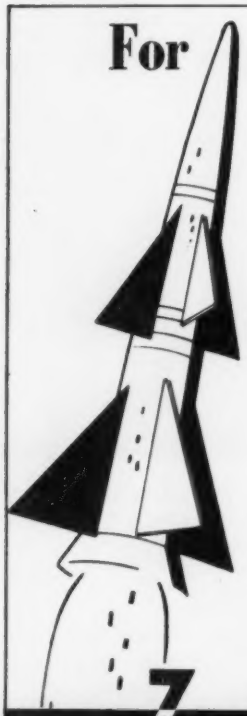
Ceramic Fuels

Some ceramic fuels appear to be better suited to this service because they are resistant to oxidation at high temperature. In addition, diffusion coefficients for fuel and fission products are lower in ceramics than in metals. Difficulty in preparing pore-free ceramic bodies might make the release of fission gas a problem at high temperature. A recent technique that promises to overcome this difficulty involves ceramic coating of individual fuel particles. A number of coatings that can be applied in near theoretical density by chemical techniques are being studied. Alumina is a good example. When it is used to coat UO_2 particles, the ratio of the release rate of the fission gas to its production rate is 10^{-6} over several hundred hours at temperatures up to 1500° F. Figure 1 shows the microstructure of this type of fuel element. The uniform alumina coating, 50 microns thick, is applied by vapor deposition to UO_2 particles 150 microns in diameter.

In ceramic-coated fuels, fission gas may cause cracking due to lack of ductility and thermal shock resistance. Serious heat transfer disruptions also accompany cracking. Cermet-type fuels show better behavior in this respect. Compaction of metal-coated fuel particles produces highly symmetrical structures – even for very low metal contents (around 12 to 20%) – which exhibit an almost ideal blending of the best properties of dispersion and all-ceramic fuels.

Although few data are available, it appears that ceramic matrix fuels may have some potential for flight applications. Dimensional stability under irradiation is open to question, but it is possible that satisfactory performance can be obtained if fuel particles are kept large and operating temperatures are kept high. In a recent irradiation experiment at 1500° F. (uranium burnups of 0.5 to 1.0%), no swelling occurred in UO_2-

For metals going places



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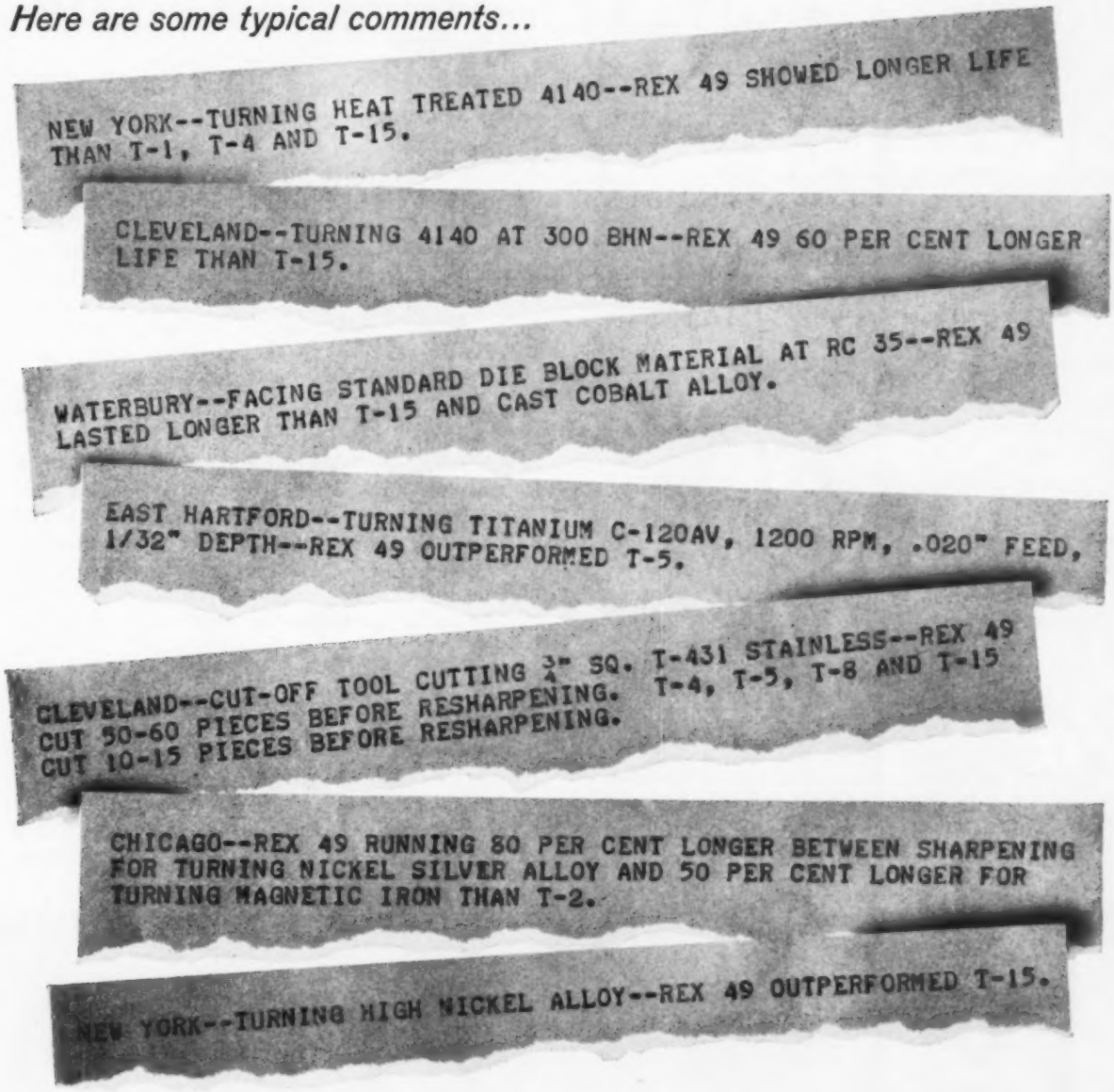
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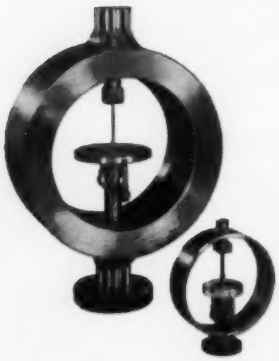

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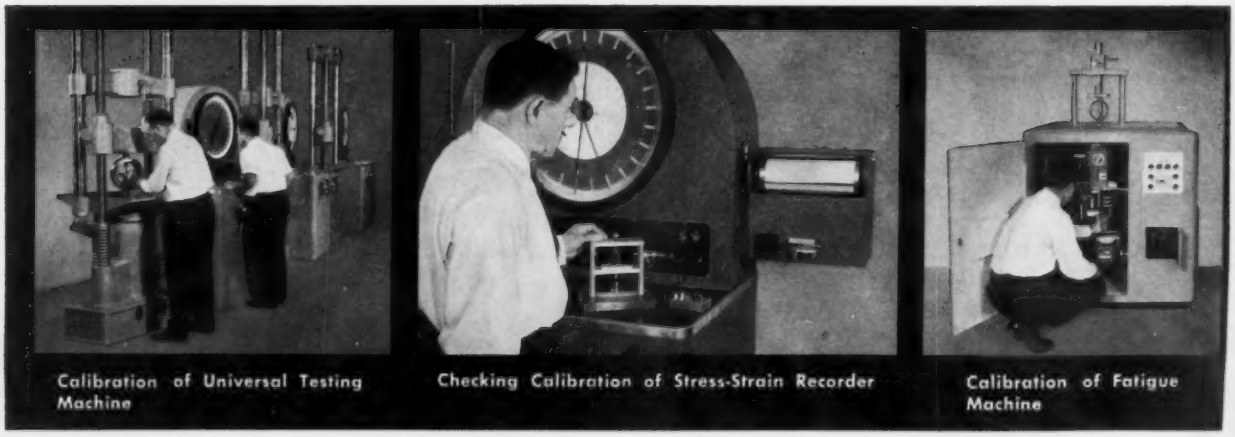

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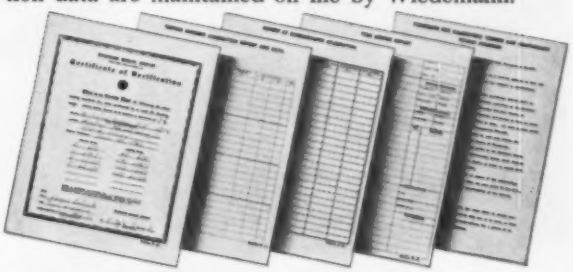

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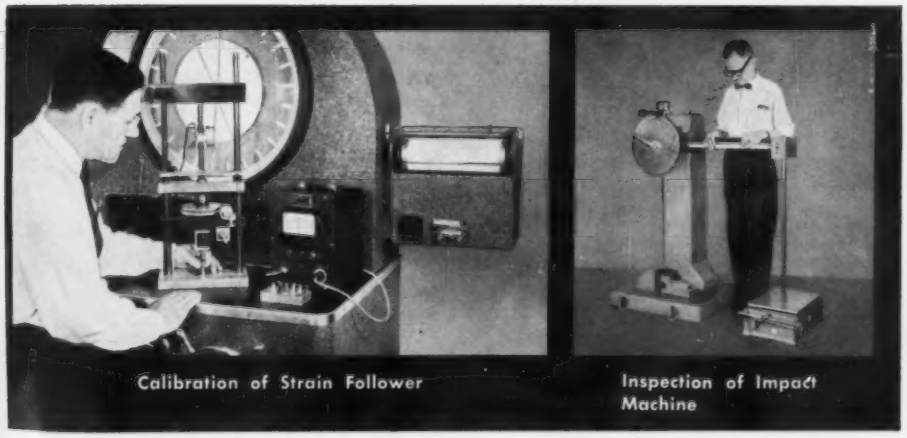

Calibration of Strain Follower

Inspection of Impact Machine

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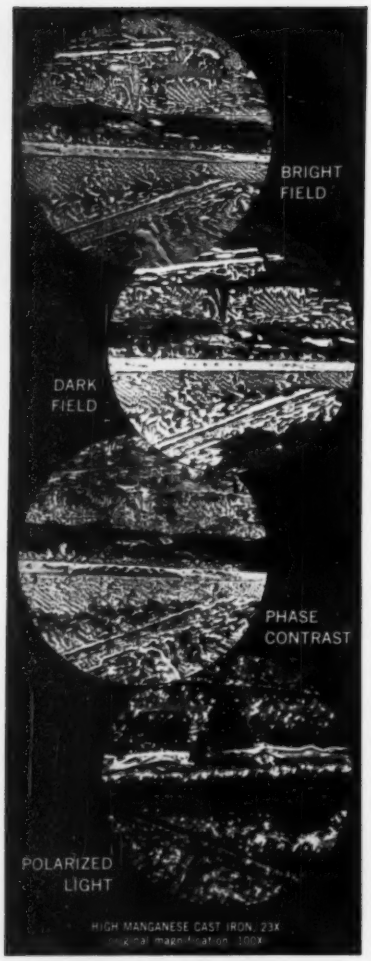

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Nucleonics . . .

BeO and UO_2-Al_2O_3 structures.

While it is a good high-temperature fuel, UO_2 presents problems when used in an oxidizing environment. Any failure of a protective coating or cladding can result in transformation of UO_2 to U_3O_8, a change which is accompanied by a volume expansion and an increase in vapor pressure. This transformation may be prevented by additions of other oxides to UO_2. It has been found that massive additions of La_2O_3 or Y_2O_3 promote retention of the fluorite structure in air at temperatures in excess of 3360° F. (1850° C).

Fabrication of Cermet Fuel Elements

It was in the HTRE tests that the feasibility of operation of turbojet engines by nuclear power was clearly established. The fuel element in this reactor is a series of metallic, concentric rings containing UO_2 dispersed in a nickel-chromium matrix and protected by a nickel-chromium cladding (see Fig. 2). Fabrication involves many common and some unique processes including powder metallurgy, comminution, mixing, brazing, sintering, hot pressing, welding, rolling, annealing and pressing.

Nickel, chromium, and UO_2 powders are blended and cold pressed into a fueled-core compact and then sintered in dry hydrogen at 2200° F. The edges of the core are protected by a frame made of pressed and sintered nickel-chromium powders. Wrought 80 Ni, 20 Cr sheet is attached to the flat surfaces of the core and the assembly is hot pressed to obtain a metallurgical bond between the cladding and the powder compacts. This product, called a billet, is rolled into ribbon of suitable thickness, cut into short pieces, and the exposed fueled core is sealed by brazing. The pieces are then roll formed into circular rings of various diameters which are assembled into a concentric configuration, called a stage, by tack welding and brazing. Eighteen in-line stages form the cylindrical fuel cartridge.

A unique development is an automatic edge-cutting device which trims the "picture frame" to a nominal width of 0.015 in., ±0.005 in. An x-ray beam operating in conjunction with a servo-mechanism locates the unfueled edge and actuates a high-speed nibbler.

Processing variables have a profound effect on physical properties and performance of fuel elements in a reactor. As an example, a tack-welding operation prior to brazing caused microscopic fissures which permitted ingress of oxygen into the fuel ribbon thereby causing swelling to occur during reactor operations. To prevent this, very close technical control of the process was required.

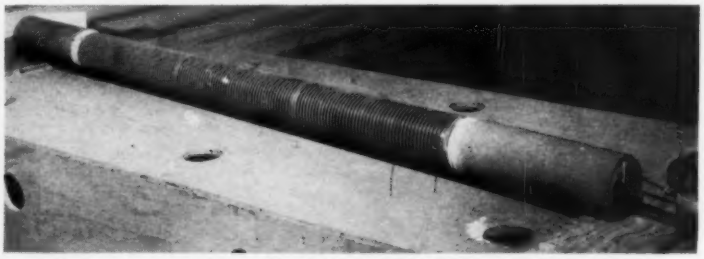

Fig. 3 – Photograph of HOTCE (Hot Critical Experiment) Fuel Element. a cermet wire fuel element, containing 33% UO_2, is coiled around a refractory cylinder before insertion into test facility

Another paper on fuel-element fabrication involved the manufacture of cermet wire fuel elements. These elements were required for a facility in which effects of variations in moderator temperatures could be evaluated. In 1958, the Aircraft Nuclear Propulsion Dept. of General Electric Co. constructed a hot critical experiment (HOTCE) facility in which wire fuel elements provided nuclear reactivity while at the same time electric current was passed to heat them to controlled temperatures. The wires, 0.125 in. in diameter, containing 33 wt.% UO_2 in the core; the matrix and cladding were Type 310 stainless. The wires were subsequently formed into hel-

ices and coiled around refractory cylinders for insertion into the test facility (Fig. 3).

Although much development work had been done on fabricating cermet wires by blending UO_2 and stainless steel powders, cold pressing into pellets, encapsulating, hot rolling, swaging, and cold drawing, a decision was made to form the wire by hot extruding the capsules roughly to size and cold drawing to final dimension. The extruded product was superior in core concentricity to that produced by hot rolling; however, some loss of ductility was encountered, as evidenced by breaking and cracking during wire drawing.

To provide wires of sufficient length to form a complete helical coil for each element, it was necessary to join three lengths of wire. Adequate control of core length was difficult and it was necessary to join the wires at locations containing the core. The joining technique, a combination brazing and resistance butt welding operation, is apparently successful, since the reactor has been operating satisfactorily.

Indirect-Cycle Systems

Indirect-cycle jet power and space systems employing a nonoxidizing coolant, or direct-radiation cooling, will allow a little more latitude in the choice of fuels (compared to direct-cycle systems), although operating conditions will be no less formidable. In nuclear rockets, for example, fuels must operate at temperatures over 4500° F.

In the program to develop nuclear auxiliary power systems for space, the SNAP-2 reactor, a dual-cycle turboelectric system, uses cylindrical homogeneous fuel-moderator elements made up of a zirconium hydride-U^{235} mixture clad with thin-walled stainless steel tubes coated internally to minimize hydrogen loss. The NaK coolant leaves the beryllium-reflected core at 1200° F. The initial version of this reactor operated continuously for 1000 hr without trouble; later versions will run at higher temperatures. More demanding from the materials standpoint will be SNAP-10. This large-capacity the moelectric device will employ flat plates of the same type used in SNAP-2, but cooling will be by conduction to space through fuel and beryllium reflector plates and

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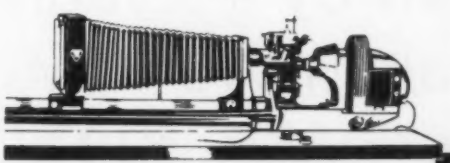

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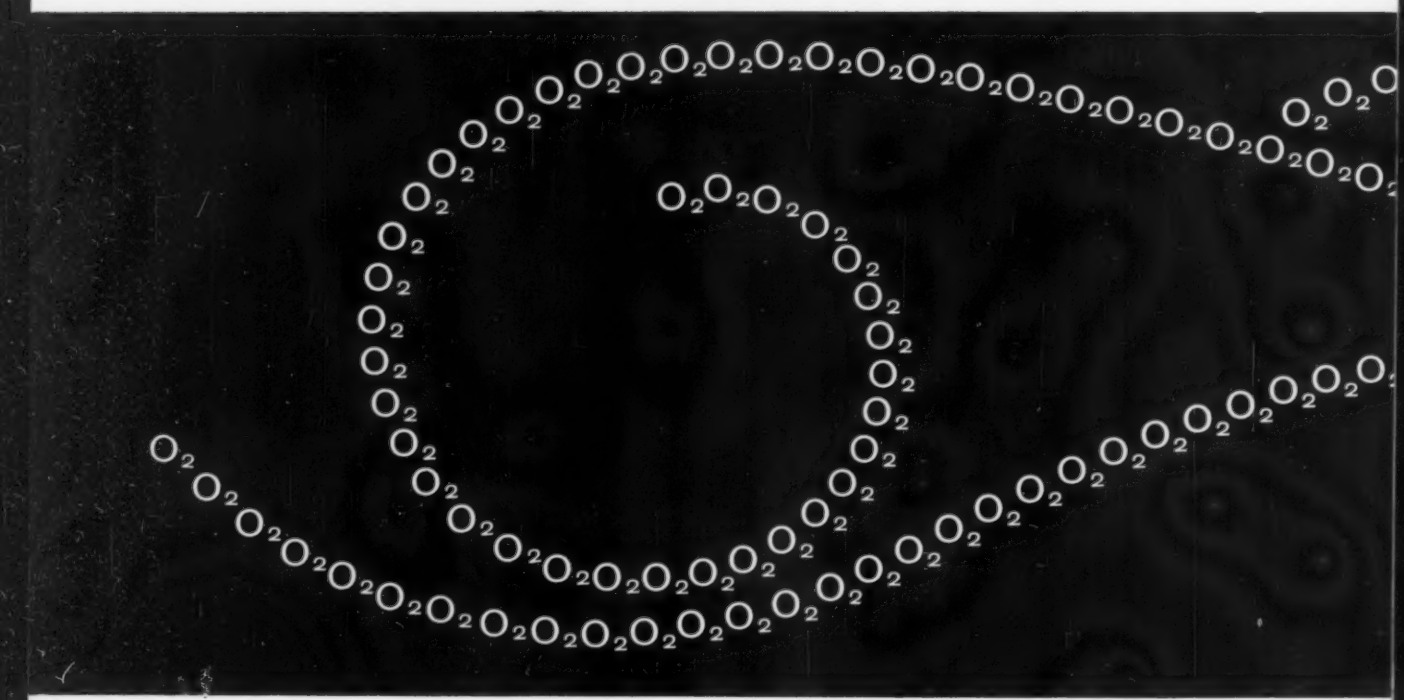

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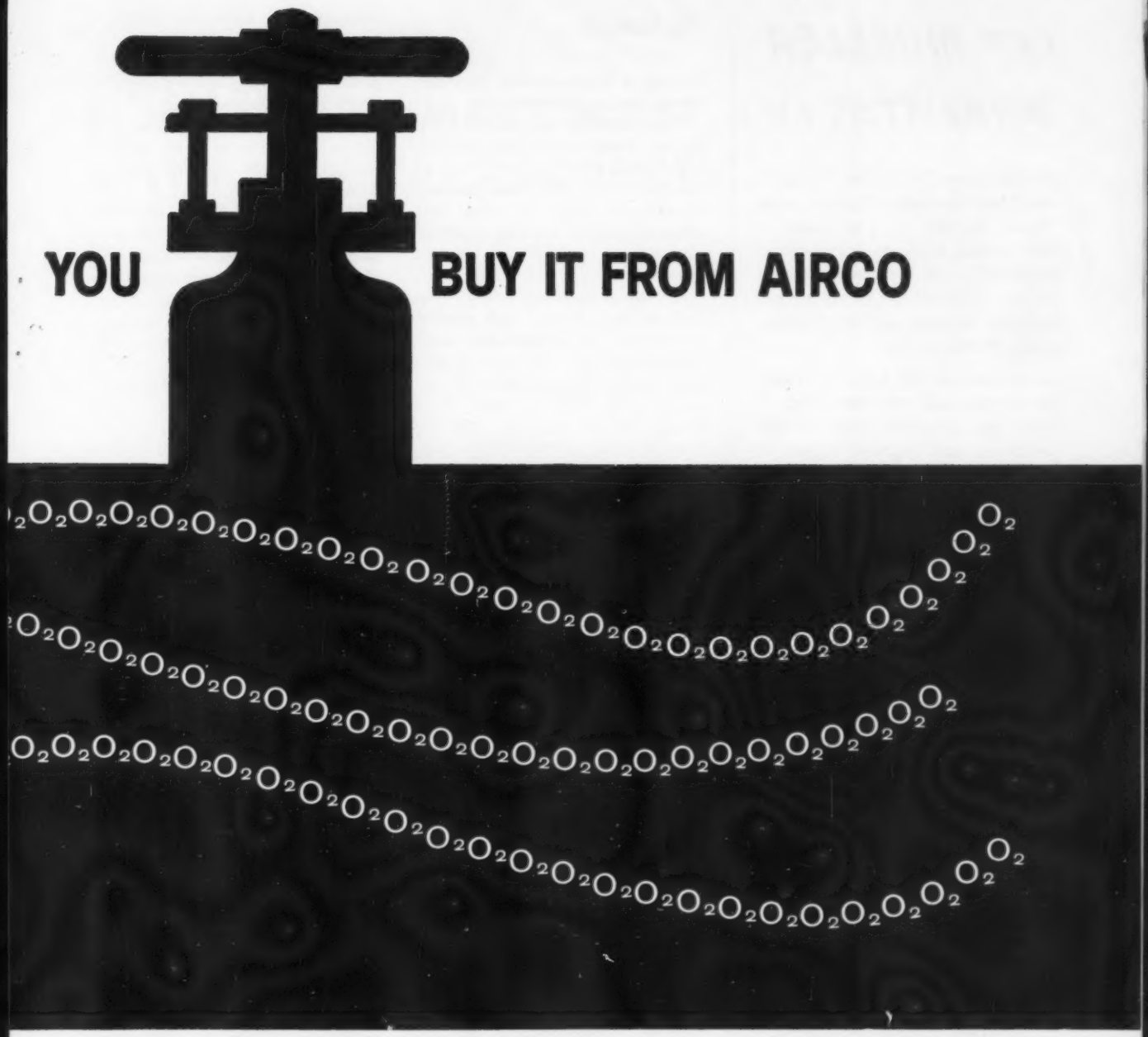

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Circle 797 on Page 48-B

Nucleonics . . .

through a thermoelectric converter section surrounding the core.

In applications such as these, refractory metals are ideal for cladding and enough is known about uranium carbide to show that it may find considerable use as a fuel. Other uranium compounds also rate study for this service, particularly uranium nitride.

Interest in uranium carbide stems from its high density, high thermal conductivity, and controllable chemical compatibility. Irradiation data accummulated recently show the material to be stable at 1500° F. to burnups of 2% uranium. The release of fission gas has been negligible in experiments to date; temperatures above 2000° F. will probably produce substantial release, however. No major microstructural changes have been noted in the compound. Some cracking occurs and excess carbon diffuses, but there is no significant volume change under test conditions.

Recent work has revealed that small additions of columbium carbide (under 10%) reduce the reaction of UC and moisture. A more serious problem is the reaction of carbide and cladding. It is unlikely that refractory metals will react with UC below 2500° F., but common alloying additions such as zirconium, titanium, and aluminum may cause difficulty. This can be minimized by introducing excess carbon, without reducing the amount of UC, so that a protective layer forms.

Structural Parts

Structural requirements of a nuclear reactor demand a material which can be fabricated into a variety of sizes and shapes. Mill products such as bar, sheet, plate, tubing and wire are needed; die impression forgings must be produced; bending, hydroforming, spinning, and flowturning are required to fabricate certain components and these must be joined by welding or brazing into subassemblies and final assemblies.

For the CANEL (Connecticut Aircraft Nuclear Engine Laboratories) program, Pratt & Whitney selected a 1% Zr columbium alloy for reactor structural applications after evaluating mechanical and physical properties and testing for compatibility with the intended service environment. The alloy also shows promise of meeting another essential requirement – fabricability. Small ingots of 1% Zr columbium alloy can be electron-beam or arc melted; tubing can be cold drawn, and sheet rolling is feasible.

Nearly 100 tons of the alloy has been melted and converted to bar, sheet, tubing, pipe, wire, and die impression forgings. Sheet has been rolled in widths up to 36 in. Seamless tubing down to ⅛ in. diameter and 0.006 in. wall has been cold drawn. Forming operations such as bending, hydrospinning, deep drawing, and machining have been performed successfully. Inert-gas-shielded arc welding is used in joining sheet up to ½ in. thick, with weld efficiencies of 90 to 100%.

One important ground rule – established at the outset and not violated during the course of the program – is that mill fabrication should not require any heavy outlay for new or advanced metalworking equipment. In nearly every respect the alloy has been produced on standard mill equipment, with excellent yields.

As a first step, it was decided to aim for low interstitial impurity levels to favor workability. A survey of available sources for starting material showed that none was especially impressive. Total carbon, oxygen, and nitrogen levels were on the order of 200 ppm. Vacuum arc melting did not effect very significant purification but high-vacuum electron-beam melting was found to be beneficial. Ingot impurity maximums were set at 300 ppm. oxygen, 300 ppm. nitrogen, and 100 ppm. carbon; hydrogen levels were generally less than 10 ppm. To provide the larger ingots required for the larger forgings, a duplex melting scheme was adopted wherein starting material was purified by electron-beam melting and then vacuum arc melted to larger ingots with no pickup of impurities. Ingots weighing over 2500 lb. and up to 16 in. in diameter are produced by the method.

The workability of the alloy is good because of relatively low mechanical properties at working temperatures. For example, even at 1200° F., yield strength is 10,500 psi., compared to 60,000 psi. for Inconel "X". At 2200° F., how-

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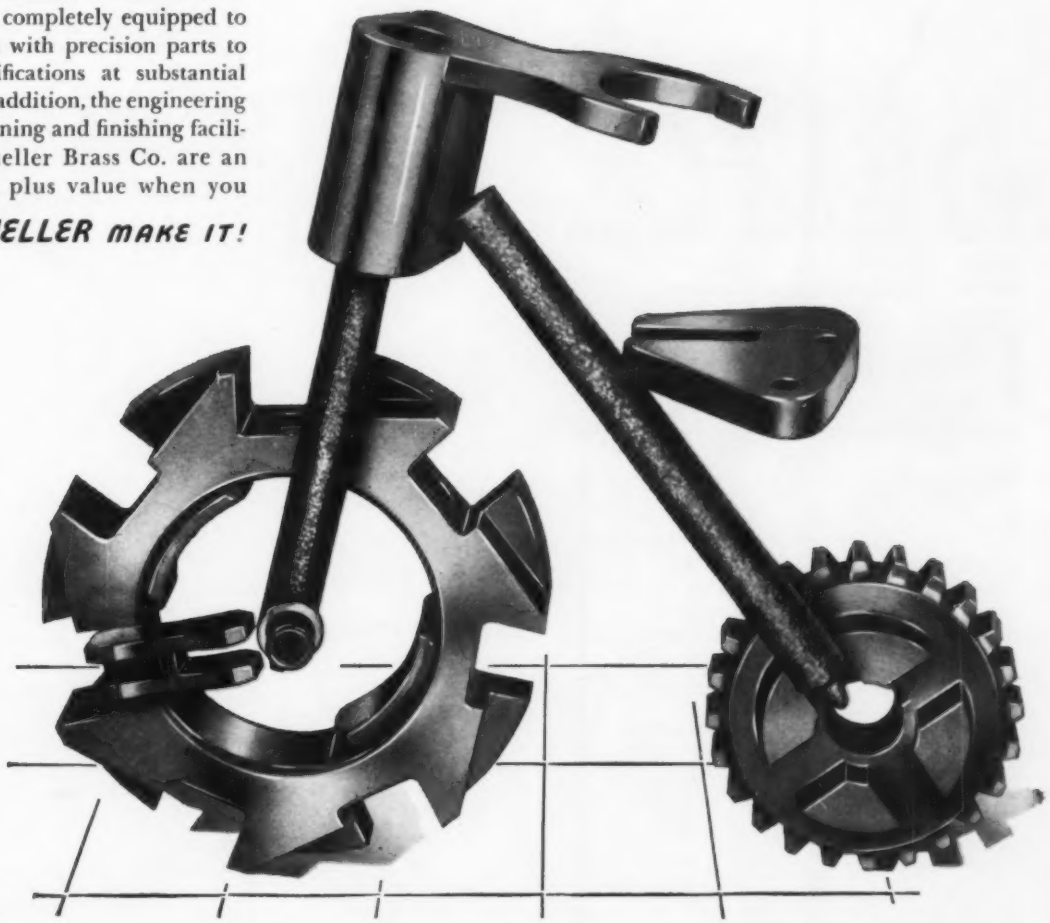

MUELLER BRASS CO.

PORT HURON 28, MICHIGAN

Circle 798 on Page 48-B

Nucleonics . . .

ever, 1% Zr columbium has a yield strength of 10,000 psi. compared to 2000 psi. for Inconel "X".

For additional comparison, the 100-hr. stress-rupture strength of the 1% Zr columbium alloy at 2000° F. is about 9000 psi. whereas Inconel "X" is about 1000 psi. Even a superior nickel-base alloy such as Udimet 700 is estimated to have a strength of 3000 psi. at 2000° F.

In working the ingot, initial breakdown is accomplished by extrusion, upsetting, open-die cross forging, or V-die cross forging. Forging is done at 2000 to 2300° F. with no difficulty. Extrusion temperatures vary with different producers; ingots have been extruded in the 600 to 800° F. range using proprietary plastic-type lubricants. In working at the higher temperatures, it is advisable to protect the alloy against contamination by ceramic coatings such as those used in titanium alloy work.

Secondary reduction to sheet, bar, forging billet, or tube blanks is done at 2000 to 2300° F., although tube blanks have been produced directly from the ingot as well as from forged billet in the 600 to 800° F. range. The alloy has good cold workability, and the conditions for stress-relief annealing (1800 to 2200°F.) are not critical. Annealing does, of course, require a good vacuum or inert gas environment.

In summary, the 1% Zr columbium alloy posseses an exceptional combination of properties and capabilities – useful strength to 2000° F.; outstanding corrosion resistance to alkali metals including molten lithium; good producibility with high yield and good quality; excellent cold formability and high weld efficiency.

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Rapid Heating and Loading

Digest of "Strength of Structural Alloys Under Rapid Heating and Loading", by J. R. Kattus and D. W. McDowell, Jr. Paper (Preprint No. 71) presented at the 63rd Annual Meeting of the A.S.T.M., July 1960, Atlantic City, N.J.

THE SERVICE LIFE of most missiles may be measured in terms of seconds or minutes. However, during their short life some of their structural components are subjected to rapidly applied stresses and elevated temperatures. The behavior of structural materials under these conditions may differ radically from that observed in conventional tests. Therefore, there is a need for investigating mechanical properties of alloys under conditions of rapid heating, rapid loading, and short exposures to high stresses and temperatures to obtain data for use in missile design.

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(Continued on p. 152)

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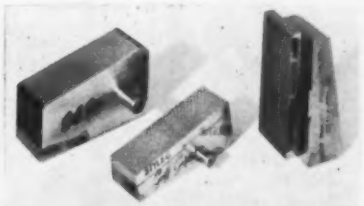

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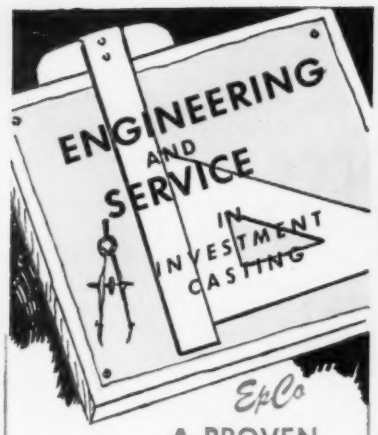

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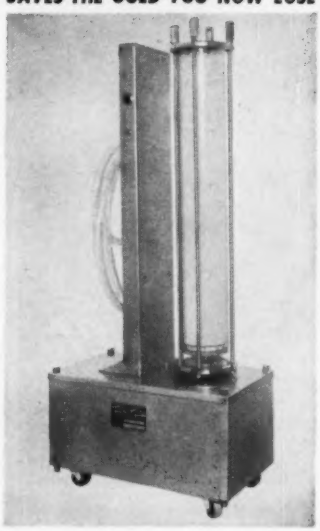

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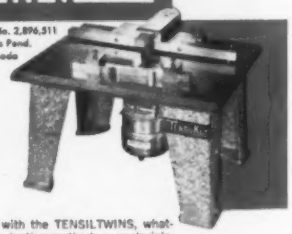

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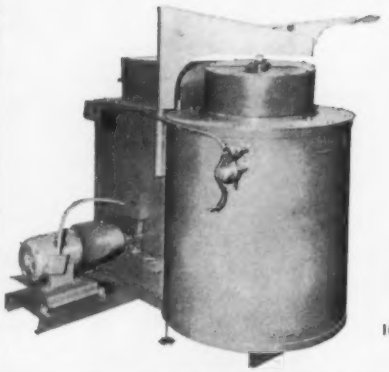

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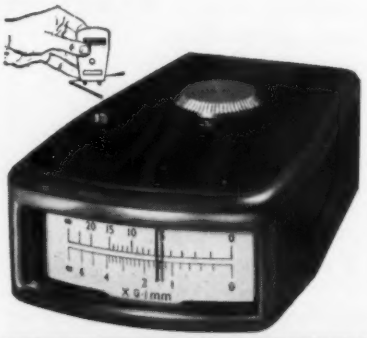

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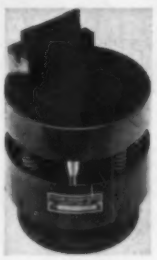

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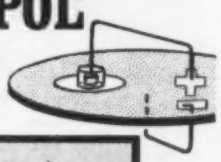

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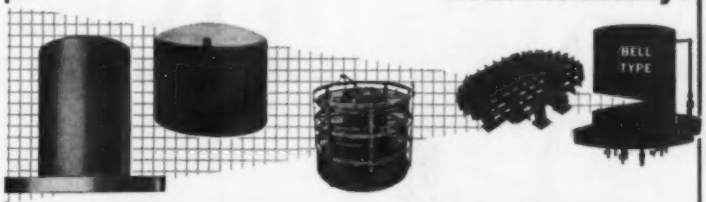

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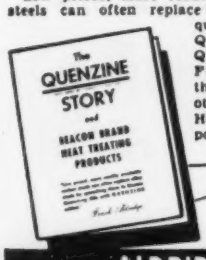

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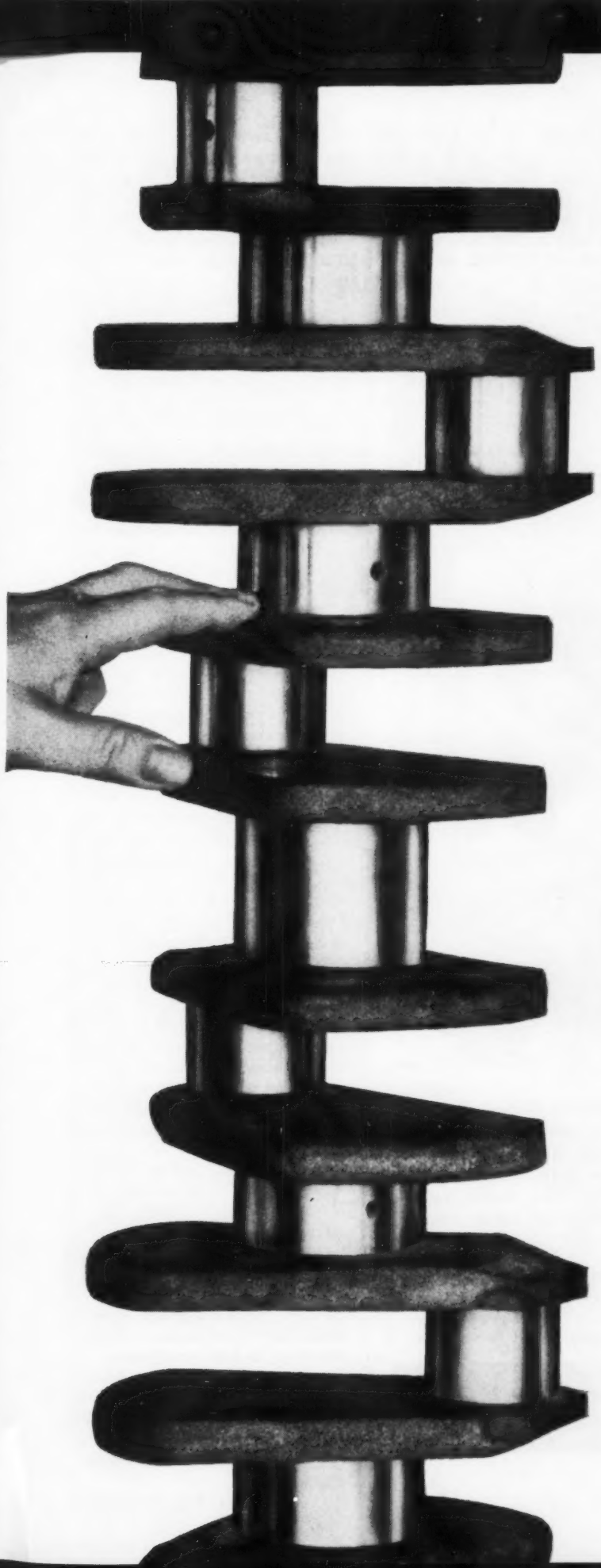

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Circle 841 on Page 48-S

Rapid Heating . . .

800° F. for 24 hr.

3. PH 15-7 Mo stainless steel which was subjected to two treatments: *(a)* (CH 900) cold reduced 60% at 75° F., aged at 900° F. for 1 hr, air cooled; and *(b)* (RH 950) heated at 1750° F. for 10 min., air cooled, frozen at −100° F. for 8 hr., heated at 950° F. for 1 hr., air cooled.

4. René 41, water quenched from 1950° F., tempered for 16 hr. at 1400° F., air cooled.

5. Inconel "X", 50% cold reduced, aged 20 hr. at 1100° F., air cooled.

6. Nimonic 90, 30% cold reduced, aged 16 hr. at 1300° F., air cooled.

All tensile tests were conducted by heating the specimens to a preselected temperature in 10 sec., holding at temperature for 10 sec. and then loading to failure at a strain rate of 0.1 in. per in. per sec. (This is about 1000 times faster than the rate used in normal tensile tests — 0.005 in. per in. per min.). With a stress-strain curve being recorded to 2% offset each time, two or three tests were made for each condition.

For the creep tests, a number of constant load levels were selected to produce rupture in each material in times ranging from 1 min. to 30 min. In each test the load was applied at room temperature. Then, the specimen was heated to the test temperature in 30 sec. and held at constant temperature and constant load until rupture occurred. The strain was recorded as a function of time during both the heating time and the holding time.

The maximum temperature was the same for the tensile and creep tests of each material. However, the minimum temperature for the creep evaluations was the lowest one at which the creep properties were a significant factor.

The following conclusions were based on the data in this study:

- The load-carrying capacity of structural sheet metals at elevated temperatures increases as the time of exposure to load decreases from 30 min. to 1 sec.
- The stainless steels tested had higher tensile strengths than the nickel alloys at temperatures up to 1000° F. Above this temperature, the nickel alloys were stronger.
- The nickel alloys exhibited useful short-time creep properties at much higher temperatures than the stainless steels with the strengths of the nickel alloys in the 1400 to 1800° F. range being roughly equal to that of the steels in the 1000 to 1400° F. range.
- Cold rolling certain austenitic stainless steels at subzero temperatures produced markedly higher short-time tensile strengths than the same operation conducted at room temperature.
- The cold worked structures of all alloys tested had greater strength than the precipitation-hardened structures at low temperatures and for short rupture times at moderately elevated temperatures. However, increasing the temperatures and the times under load reversed this.

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Circle 842 on Page 48-B

Carbon/Graphite Facts for METALLURGISTS

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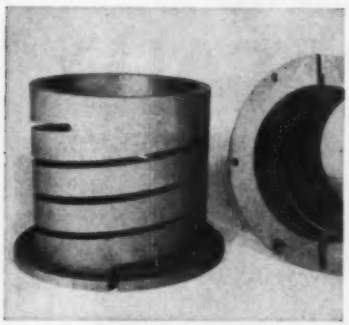
NATIONAL graphite, which is created by thousands of degrees of heat, has more useful properties for aero-space heat-resisting applications than any other material. Rocket nozzle inserts, vanes, and other components withstand temperatures of 5000° F in fractions of a second. Graphite not only maintains dimensional stability, but gains strength as temperature rises. Light, *non-melting* graphite is the top answer to spacecraft thermal needs.

Circle No. 752 on Page 48-B

HEATING ELEMENTS
for resistor-type furnaces performing up to 3000° C.



HEATING elements employing NATIONAL graphite provide excellent thermal, electrical, and mechanical advantages. Graphite elements can be fabricated to almost any configuration. The more common configurations are: hairpin or slotted plate type resistors and tubular and helical units that provide maximum resistance and require minimum space. Special shapes are readily available from NATIONAL CARBON's completely equipped machine shops.

Circle No. 753 on Page 48-B

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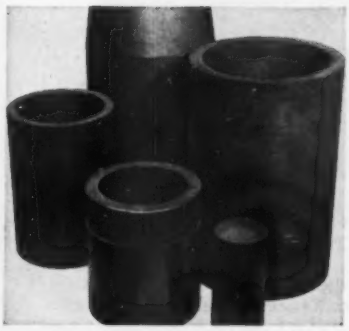

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Circle No. 754 on Page 48-B

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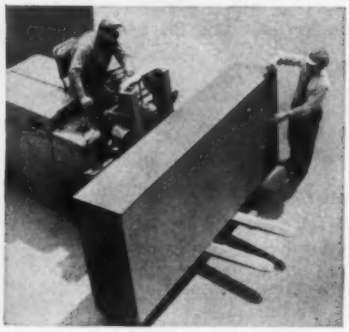

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Circle No. 755 on Page 48-B

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Wear and Lubrication Studies

Digest of "Some Studies of Wear and Lubrication", by A. W. Crook, *Wear*, Vol. 2, 1958-59, p. 364-393.

EXPERIMENTAL STUDIES of wear and lubrication carried out in recent years in England by the research staff of Associated Electrical Industries, Ltd., are reviewed in this article.

The wear experiments were generally performed dry because temperature or radiation conditions that prevent the use of fluid lubricants are becoming more common, and also because wear associated with fluid lubrication occurs only when lubrication fails. The amount of wear was generally obtained from measurements on a stationary ¼-in. pin held with either its end or its side against a 1-in. ring mounted on a shaft rotating at any desired speed at right angles to the pin.

The volume of material worn away from the pin when the load was kept constant was, in many instances, proportional to the sliding distance. Thus, the wear rate, defined as the volume of wear per unit sliding distance, remained the same even though the area of the wear scar kept increasing and the mean pressure kept decreasing correspondingly. Such results were obtained for Teflon, 60-40 brass, beryllium, copper and Stellite pins in contact with hardened toolsteel rings, and also with ferritic stainless steel against cemented tungsten carbide, and with the latter against mild steel. Tests with the brass and Stellite pins showed the wear rate to be directly proportional to the load.

Under some conditions, however, the variation of wear rate with load followed one line at low loads, a much higher one at high loads, and either line (or some value in between) at intermediate loads. This occurred with 70-30 brass against hardened steel, where the upper line, for loads greater than 0.5 kg. (1.1 lb.), was an order of magnitude higher than the lower line, which held for loads up to 5 kg. (11 lb.).

When the wear was mild, corresponding to the lower curve, the debris was a fine dark nonmetallic powder, the surface was polished, and there was little subsurface disturbance (as determined metallographically). On the other hand, when severe wear occurred, corresponding to the upper curve, the debris consisted of metallic flakes, the worn surfaces were rough, and there was considerable subsurface disturbance. Electrical resistance between the pin and the ring was high for mild wear, and very low for severe wear; this indicated that the surface was oxidized in the first instance, and metallic in the second.

Radioactive tracer studies of the mild wear of a soft steel pin against a hardened steel ring showed that the wear particles coming from the pin first became attached to the ring. Only later did this transferred material come off as debris. Inactive rings rotating against radioactive pins became increasingly radioactive until an equilibrium activity was reached, which was independent of the load. However, the time to reach this equilibrium condition decreased as the load was increased. Substitu-

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Circle 845 on Page 48-B

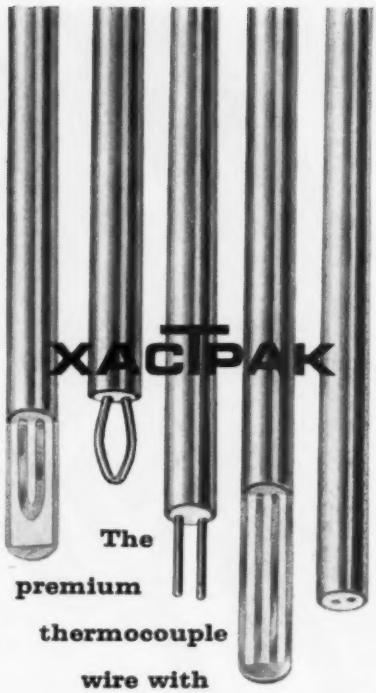
Wear and Lubrication . . .

tion of one pin for another during the course of an experiment did not disturb the amount of transfer or the wear rate. This made it possible to exchange a radioactive pin for an inactive one or vice versa. By this means, it was shown that material transferred from the pin to the ring did not transfer back to the pin.

The debris was Fe_2O_3 in the form of a fine black powder. It came from radioactive gray patches in the wear track on the ring which were about 0.5 micron thick and formed the actual rubbing surface. The explanation offered for these phenomena is that particles from the pin welded on to the ring, and were then smoothed out and joined with other such particles to form the gray patches. These oxidized on becoming hot, and eventually sloughed off to form the debris. Fresh transfer of material from the pin occurred wherever the ring surface had been cleaned off. Thus, the factor limiting both transfer and wear was the rate at which the transferred layer oxidized. Not all mild wear proceeded in this fashion. When a hard steel pin rubbed against a hard steel ring, the wear mechanism that was eventually predominant was abrasion of both surfaces by aggregates of submicroscopic oxide particles.

In the severe wear of 60-40 leaded brass against hard steel, the debris again was derived entirely from a transferred layer, but it was metallic. The wear particles were the same size as the individual transfer patches. The linear increase in wear rate with load was due to an increase in the particle size rather than in their number. The wear particles were flakes whose thickness, about 15 microns, was independent of the lead.

The wear process can change the nature of the surface and cause it to become complicated and irregular. Thus, mild and severe wear may occur alternately or even simultaneously; or a heavy load may thermally harden a steel surface so that the initial severe wear changes to mild wear while an identical piece subjected to a lower load may continue to undergo severe wear because insufficient heat is generated to harden it. Steels too low in carbon to be capable of hardening



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Circle 846 on Page 48-B

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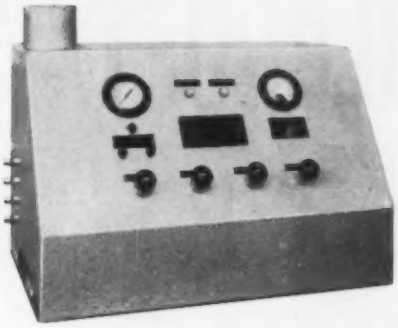

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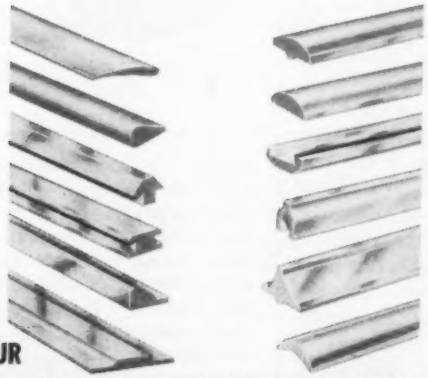

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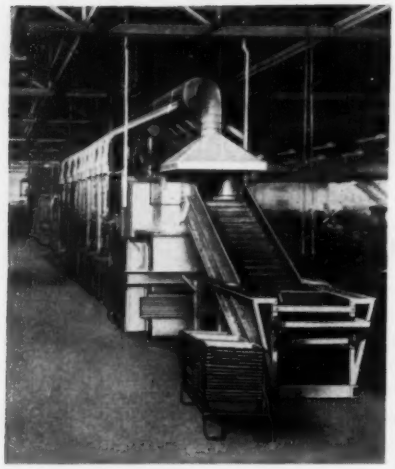

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Circle 847 on Page 48-B

Wear and Lubrication . . .

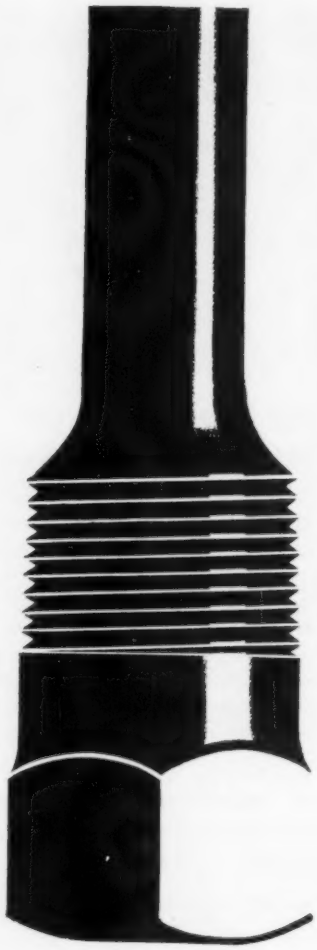
sufficiently in this manner may harden because the surface has absorbed nitrogen from the air or carbon from a lubricant.

Studies of Lubrication

Lubrication studies were performed with the aid of rotating disks, which can simulate the rolling and sliding notions of contacting gear teeth. Even at the extremely high contact pressures characteristic of turbine reduction gears, electrical resistance measurements showed that lubrication was essentially hydrodynamic when the disks had been run against each other for a sufficient time to become smoothed over. Initially, the resistance was less than 1 ohm, corresponding to a boundary layer which permitted the disk surfaces to come in contact at their high points. As these wore away (during a period of 10 hr.), the resistance gradually increased to 50,000 ohms, corresponding to a continuous hydrodynamic film about 1 micron thick.

It is difficult to determine actual film thickness because of complications introduced by the effect of high pressure on the viscosity of the oil and on the deformation of the disks in the vicinity of their closest approach. A method that was used successfully was to measure the electrical capacitance of the film between each disk and a flat pad floating on the film and located 90° from the conjunction of the disks. It was found that as the load was increased above 2.5 kg. per sq.cm. (36 lb. per sq.in.) of disk width, the film thickness decreased less rapidly than expected on the assumption of constant viscosity; and that above 20 kg. per sq.cm. (290 lb. per sq.in.) the film thickness remained approximately constant because of the deformation of the disks combined with the continued increase in viscosity. Over a range of loads and speeds, the film thickness was of the order of 1 micron for both rolling and sliding conditions.

Although the thickness of the oil film between the disks was not affected very much by the load, it was quite sensitive to the surface temperature of the disks. This was demonstrated by turning the oil off after the disks had been running



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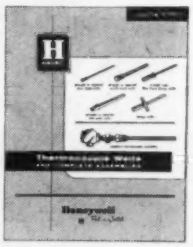

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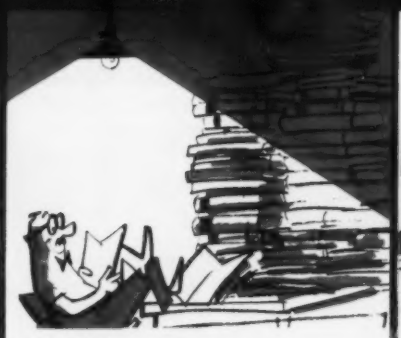

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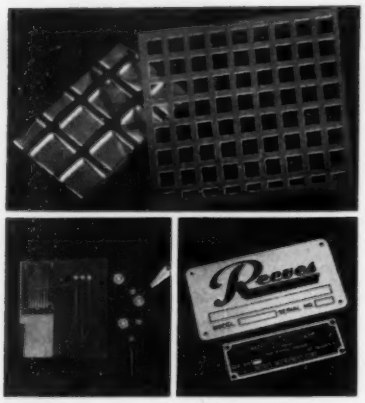

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Circle 849 on Page 48-B

Wear and Lubrication . . .

long enough under rolling conditions for equilibrium to be established. The film thickness decreased gradually to a somewhat lower value while the disk temperature increased gradually. But when the oil was turned on again, the film thickness and the disk temperature gradually approached their former levels. Had the initial drop in film thickness been due simply to a progressive oil loss after the oil was turned off, then the original thickness should have been quickly restored when the oil was turned on again.

Similar results were obtained under combined rolling and sliding conditions, which led to a considerably greater rise in the temperature of the oil where it was squeezed between the disks. It was concluded that this temperature had relatively little effect on the film thickness, and that it was the disk temperature that determined the viscosity and thickness of the oil entering the pressure zone between the disks.

In as much as highly polished disks were used in the work described above, parallel results will not necessarily be obtained in actual practice; ordinary surfaces may fail by scuffing or pitting before they can be worn in to a comparable smoothness. Failure from scuffing that occurred when the full load was applied initially did not occur when the load was gradually built up so that essentially hydrodynamic lubrication was permitted to exist between the disks at all stages. The delay observed between the application of the scuffing load to the disks and the initiation of visible scuffing was apparently due to the time required to raise the surface temperature, and thus reduce the film thickness so that the high spots that were still present could come in contact.

Pitting, which can occur in the absence of scuffing, is due to the development of fine cracks which spread and eventually leave craters in the surface. Experiments with mild steel disks, on which radial wire markers were embedded, indi-

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Circle 850 on Page 48-B

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Circle 851 on Page 43-B

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Wear and Lubrication . . .

cated that the observed occurrance of pitting only on the slower moving surface was associated with the greater shearing of that surface layer relative to the rest of the disk.

L. P. TARASOV

Base-Metal Thermocouples

Digest of "Basic Studies on Base-Metal Thermocouples", by J. F. Potts, Jr., and D. L. McElroy. Paper (Preprint 158A) presented at the S.A.E. National Aeronautic Meeting, April 1960, New York.

THE AUTHORS DESCRIBE some of the studies which have been conducted on base-metal thermocouples up to 1090° C. (2000° F.) at the Oak Ridge National Laboratory and the University of Tennessee Engineering Experiment station. The three questions asked were: How reliable are Chromel-P/Alumel thermocouples up to 1000° C. (1830° F.)? Why is this combination good or bad? Furthermore, does a better combination exist?

To answer these questions, the authors carried out life tests in air, under static and time-varying temperatures from 150 to 1000° C. (300 to 1830° F.) on a variety of nickel-base alloys. During these tests, information was collected on the change of thermal emf. with time at temperature, the effects of methods of fabrication, and protection by encasement and alloying.

They found that up to 390° C. (735° F.) no one commercial thermocouple had a particular advantage up to 6000 hr. Cold working and oxidation effects were reduced in this temperature range.

The high-temperature tests (880 and 980° C. or 1615 and 1795° F.) showed differences between normally handled (bare hands, without solvents) and specially handled (gloves and solvents) thermocouples at 880° C. The normally handled 20-gage Chromel-P/Alumel thermocouples perform better than the others. However, a comparison of the mean of the standard deviations indicates that the spread of data of the normally handled couples is eight times that of the specially handled. The drift at 980° C. (1795° F.) is more than at 880° C. (1615° F.), and the reducing effect of contaminants is overshadowed by oxidation effects. But again there is a greater spread in the normally handled couples.

The drift and failure performance of Chromel-P/Alumel, Kanthal P/N, and Geminol P/N at 880° C. and 980° C. showed a marked advantage to the latter combinations. The improved behavior of the latter two couples is primarily associated with the oxidation resistance of Kanthal N (2.4% Si, balance Ni) and Geminol N.

To check the effect of silicon on nickel as a thermocouple wire, drift tests were run on solid-solution alloys of 0, 1, 2, 3, 4 and 5% Si in nickel. These tests showed that small drifts were observed in all materials except in the 1% Si alloy. This drift is associated with the poor oxidation resistance of the 1% alloy,

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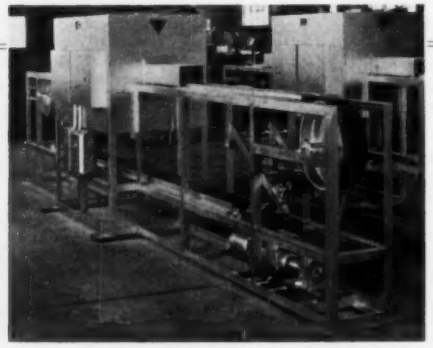

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Circle 853 on Page 4B-8

and the large effect a small amount of silicon has on the thermal emf. of nickel. Microstructural examination and weight-grain tests on these alloys indicated that the amount of oxidation decreases uniformly up to 5% Si.

In regard to the Chromel-P alloy, the authors showed that in an argon atmosphere the carbon present in the alloy can cause the precipitation of chromium carbide. However, the consequent removal of chromium from solid-solution produces a maximum change of 1° C. at 450° C. In an environment where a carbon source exists (carbon monoxide, for example), a precipitate formed at the grain boundaries and caused a large change (about 20% decrease) in the thermal emf.

To sum up: Commercial thermocouples drift less than ±1° C. below 390° C.; Special handling of thermocouples may not produce less drift at a given temperature, but does reduce the spread in emf. The addition of 2 to 3% Si to nickel results in an alloy superior to Alumel as a thermoelement; in an inert atmosphere there is not enough carbon in Chromel-P to cause a detectable change in its thermal emf.

W. A. MORGAN

Nickel Plating by the Kanigen Process

Digest of "Chemical Nickel Plating On a Large Scale by the Kanigen Process", by W. L. Crehan. Paper No. 59-A286 presented before the Annual Meeting of the A.S.M.E., December 1959, Atlantic City, N.J.

THIS ACCOUNT OF APPLICATIONS for electroless nickel-plating process includes a description of a procedure for coating the inside surface of railroad tank cars, cast iron pump casings, and manifolds. According to the author, similar procedures have been used for plating high-pressure gas storage bottles, fuel injector plates and nozzles for launching rockets, fuel pumps and fuel metering devices for jet aircraft, steel pump shafts and valves for petroleum products, hydraulic cylinders for gas heat exchangers, titanium hydraulic cylinders, and others items.

About 150 tank cars have been plated in three years to provide protection for caustic soda, ethylene oxide, tetraethyl lead, oil, glucose, rosin size, fatty acids and glycerine. The procedure for preparing tanks for plating illustrates the need for thorough and complete cleaning, which is just as important for electroless plating as it is for electroplating. After alkaline cleaning and treatment with acid, plating solution is pumped into the vessel, which is rotated on its major axis. Solution drained from the tank is regenerated, filtered, and reheated externally.

Gas entrapment, which inhibits plating, is prevented by rotating the vessel. In instances where rotating is impractical a rocking fixture is employed. Castings and other parts plated on external surfaces also are "fixtured" for movement to prevent gas entrapment.

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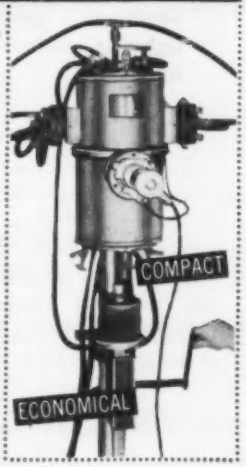

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Circle 854 on Page 48-B

Nickel Plating . . .

are too large to fit into the salt bath at hand, they are sand-blasted instead. Pickling and alkaline cleaning steps are reduced to a minimum to prevent smut formation, which is attributed to the carbon present in the castings.

The author does not indicate the thickness of the coating deposited on tank car surfaces or cast iron casings, but the thickness for other applications ranges from 0.001 to 0.005 in. on steel components. Thinner coatings are deposited on aluminum to prevent wear, on titanium to prevent galling and on stainless to prevent stress corrosion.

Some of the properties of the chemical nickel deposits, containing 8 to 10% P, are discussed. The author refers to the deposit as "amorphous" because x-ray patterns showed no evidence of individual crystals and were "similar" to patterns for glass and plastics. Crystallization occurs by heat treating at 400° C. (750° F.), which also increases the Vickers hardness of the coating from 550 to 1000. Heat treating at a higher temperature softens the coating, but improves its ductility.

High strength steel suffered no loss in tensile strength when plated with chemical nickel and heat treated for hydrogen relief, nor was its capacity for impact energy absorption altered. Endurance limit, however, was reduced 25%.

The cost for plating the chemical nickel on flat pieces is said to be eight to ten times the cost of nickel electroplating. On complex shapes where special anoding would be required for electroplating, the cost for chemical nickel plating becomes comparative or even lower. In place of corrosion-resistant alloys or clad steel, electroless nickel can effect "considerable savings", according to the author.

For additional information on the history, theory, and practice of electroless nickel plating, the reader should consult A.S.T.M. Special Technical Publication No. 265, "Symposium on Electroless Nickel Plating" (American Society for Testing Materials, Philadelphia, Pa.)

W. H. SAFRANEK

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Circle 856 on Page 48-B

Spark Hardening

Digest of "Spark-Hardening of Metals", by N. C. Welsh, *Journal* of the Institute of Metals, Vol. 88, 1959-60, p. 103-111.

EARLY EXPERIMENTS CONCERNING the effect of electrical sparks struck between contacts of electrolytic iron revealed that the scratch resistance increased greatly in the heated zone. Since copper and nickel contacts were not so affected, the surprising hardness increase in the low-carbon iron was attributed to the rapid chilling of minute volumes.

Recent publications described the Russian work on spark hardening and its application to practical problems of surface hardening of ferrous materials. Further, two firms in Britain are marketing spark-hardening equipment. Despite the practical success claimed for the process, no detailed description of the constitutional changes produced by sparks has been given.

In these experiments, as in Russian practice, a succession of sparks was produced by the action of a vibrating electrode which repeatedly made and broke contact with the workpiece surface. Two types of power supply were used. To study the general effects of thermal pulses, the researchers employed a small transformer having 8 or 20-v. taps. On the other hand, when the principal objective was to transfer

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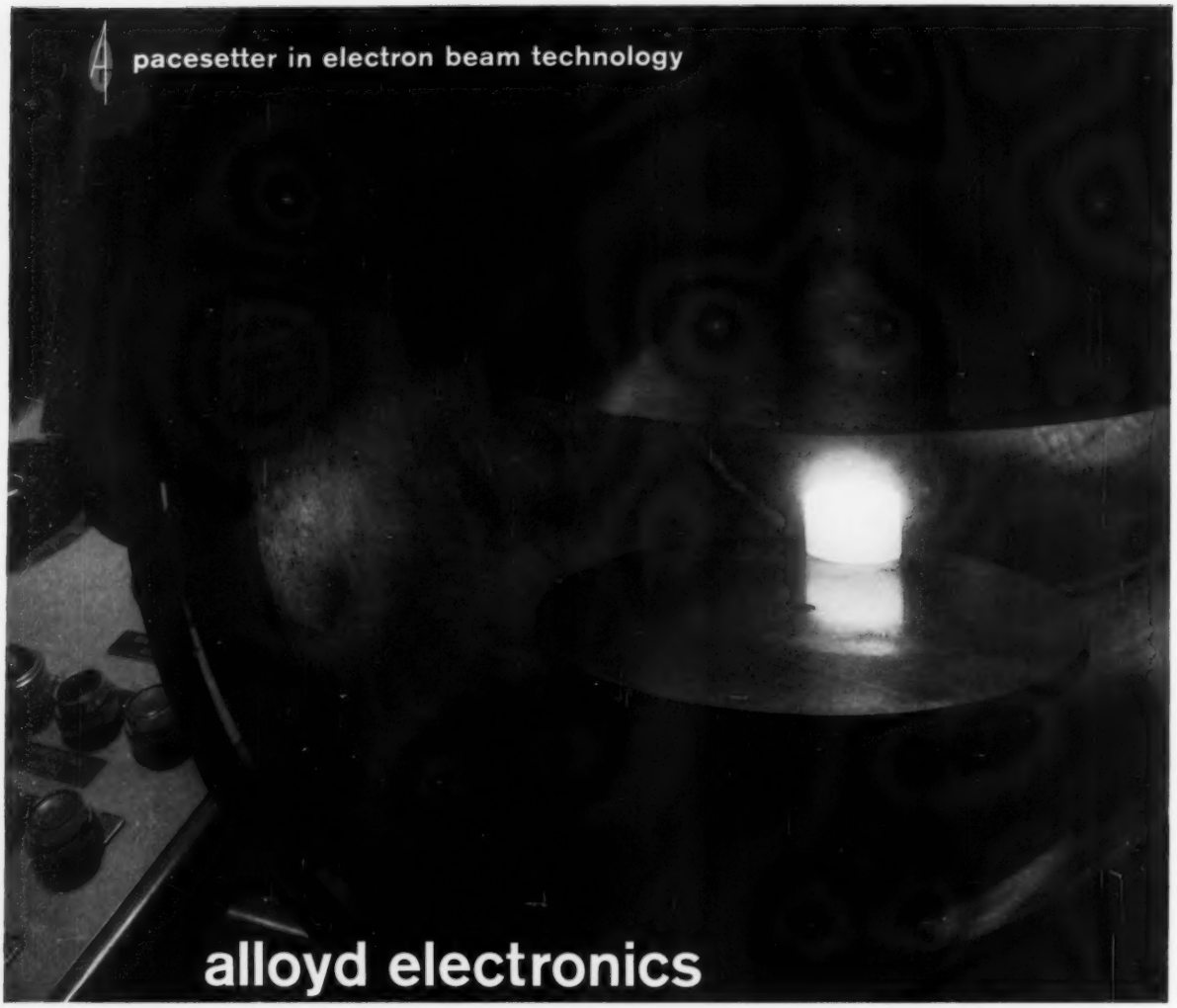

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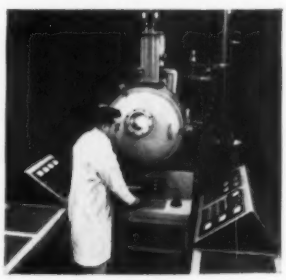

Circle 857 on Page 48-B

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Spark Hardening . . .

electrode material, current was drawn from condensers charged by a 120-v. rectified source.

In some experiments the electrode was traversed over the workpiece surface by hand control. However, to assure uniformity, particularly for wear-test specimens, a mechanical traverse was often employed. Certain of these experiments were carried out with an electrode of the same material as the workpiece, a procedure which has been designated "self-sparking".

The brief, but intense, heat of the spark produces steep temperature gradients in the metal surface. Two important thermal zones can be recognized: (*a*) that in which the temperature reached a point between the melting point and the boiling point of the metal, and (*b*) that in which the temperature was less than the melting point but high enough to modify the structure. Since the mass of metal heated in each spark is minute compared to the bulk of the piece and the duration of heating is short, the cooling rate is extremely rapid, and the austenite formed can be expected to transform to martensite.

To determine the influence of thermal treatment affected by the spark in the absence of all intentional alloying, plain steels of various carbon contents were self-sparked, and the surface hardening was measured. If the spark action simply produced a local quench hardening, the hardness of the product would be expected to vary with the carbon content of the steel. However, the hardness of the melted zone proved to be insensitive to carbon content – and even pure iron attained a value of Vickers 850. In contrast, the heat-affected, but unmelted, zone hardened to levels characteristic of normally heat treated steels.

To test the hypothesis that the hardenability of the fused metal is increased by reaction with atmospheric gases, the experiments were repeated in distilled water to shield the spark from the atmosphere. The theory was proven when hardness values of the fused zone were then found to agree closely with the quenched hardness of steels of the same composition.

The most likely atmosphere contaminant is nitrogen since this element is analogous to carbon in its influence on the allotropic forms of iron. Microchemical analyses of air-sparked surfaces revealed a substantial increase in nitrogen which was believed to be large enough to account for the observed hardness.

The effect of fortuitous alloying with atmospheric elements is equivalent to an increase in carbon content. The carbon content can be increased during spark treatment either by immersion in a hydrocarbon or through the use of a graphite electrode. Workers tried both systems, and found that carbon was more readily assimilated from a graphite electrode than from decomposed oil. Further, the former technique resulted in less surface erosion.

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Circle 865 on Page 48-B

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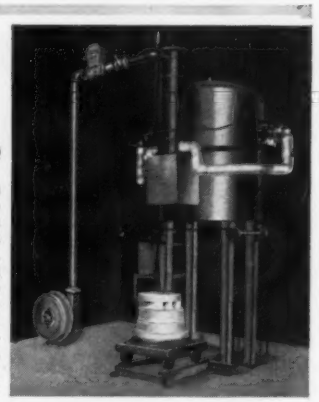

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Circle 858 on Page 48-B

The production of iron carbide on surfaces sparked with graphite confers a degree of hardness exceeding that of martensitic steel. Carbides of greater intrinsic hardness than iron carbide were formed by introducing finely divided metals, which formed hard carbides, into the spark zone. (Such metals included chromium, molybdenum, tungsten and tantalum.) Hardnesses as high as Vickers 2000 were observed on surfaces treated with tantalum powder.

During sparking, matter may be transferred by several processes, and the degree of alloying will be determined by the rates of erosion and of electrode transfer. Experiments made using hard-metal carbide electrodes demonstrated the transfer of material to the workpiece. The depth of alloying was observed to be about 0.10 mm. and analysis of this layer revealed that the steel was progressively enriched with transfer material.

The wear resistances of sparked surfaces were assessed by a dry wear test with a case-carburized mild steel sample being used as a standard of comparison. Scientists noted a very marked reduction of wear rate for samples alloyed by electrode transfer from a hard carbide.

Samples of titanium and zirconium were also surface hardened by sparking. They were carburized by graphite electrodes and paraffin oil. Subsequent wear tests revealed a remarkable increase in wear resistance for both treatments.

R. F. HARTMANN

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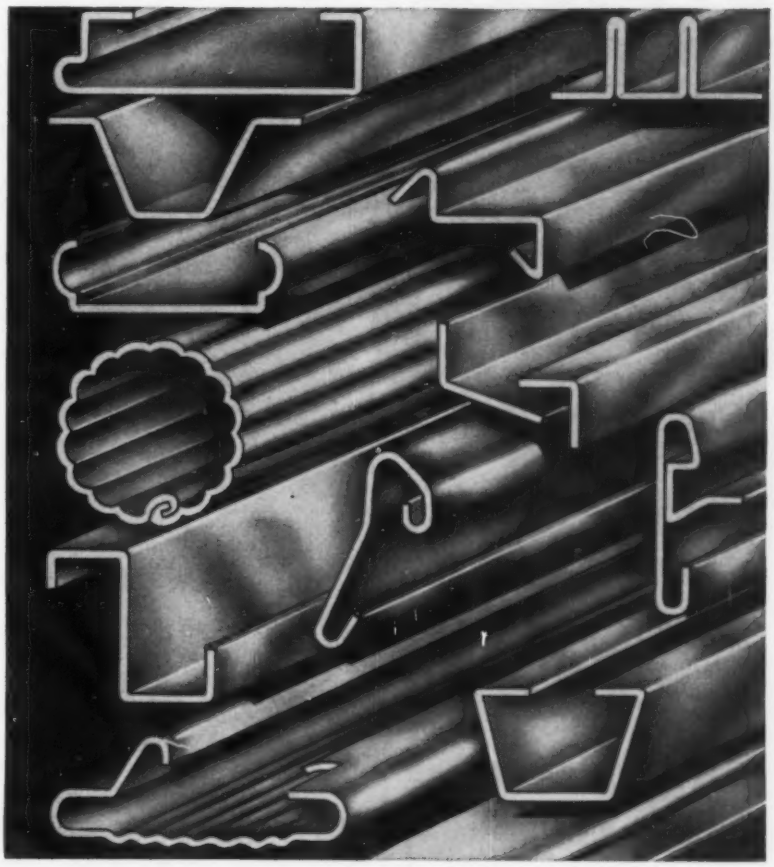

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BEHIND THE BYLINES

Leading off this month's issue are four articles dealing with various aspects of high-energy forming. In the first, "How to Design for Explosive Forming" on p. 66, **Vernon H. Monteil** of Rocketdyne points out the advantages of the process as a supplemental technique in shaping difficult materials and large parts. Recently appointed supervisor of the explosive forming unit of Rocketdyne in Canoga Park, Calif. (a division of North American Aviation, Inc.), he is working on the study of high-rate forming of complex metal parts. A graduate of the University of Notre Dame (with a B.S. degree in chemical engineering) and the University of Kansas (with an M.S. in chemical engineering), he is now working toward his doctorate at the University of Southern California. Following a three-year period at Colgate-Palmolive as a process evaluation and control engineer, he joined Rocketdyne's research department at the Propulsion Field Laboratory. His experience here has included research work on solids evaluation, nonpropellant gas generating systems, high-energy propellants and fluorine capability studies.

Ryan's experience in explosive forming is related by **Floyd A. Cox,** manager of manufacturing research and development at Ryan Aeronautical Co. in San Diego, and a member of the company's staff for 17 years. He graduated from Carnegie Institute of Technology where he studied mechanical engineering, then went on to further studies in aeronautics engineering at Curtiss-Wright Technical Institute of Aeronautics in Los Angeles. His experience has centered on the aircraft industry for the most part, first with Solar Aircraft, both in San Diego and Des Moines, and then at Convair. He came to Ryan in 1944 as staff assistant to the superintendent of production engineering, rising through various positions to his current post where the supervises the development of new techniques such as high-energy forming, machining exotic metals, chemical milling, fusion and resistance welding.

The last article in the High-Energy Forming series is based on Boeing's work in forming with explosive gas mixtures. **John Miller** (below, left) and **Philip Kruse** are both long-time staff members at Boeing Co. Mr. Miller, who is lead engineer of the explosive forming group in the manufacturing development section, majored in mechanical engineering at Pasadena City College and has worked at Boeing for 18 years. His background includes 12 years as machinist and tool and die maker as well as several years of forming

John Miller (Left) and Philip Kruse Examine a Part Blank and an Explosive-Formed Finished Gas Turbine Part

tool design. Phil Kruse, now lead engineer of the advanced projects group, has worked as lead engineer in several manufacturing development groups during his 21 years with the company, including forming, heat treating, and heat sources. He attended Seattle University where he studied mechanical engineering.

A need for "inside information" about temperatures of hot billets in a furnace led to Selas' development of "Thermolog", an analog simulator, under the direction of **Chung Liao Feng,** author of "Computer Helps Speed Heat Cycles" on p. 79. Faced with the impracticability of direct experimentation, Mr. Feng demonstrated that analog simulation could obtain necessary data on the internal temperature distribution of large billets progressing through a continuous forging furnace. An early version of Thermolog was designed and built under his direction and later expanded to its present form. He came to Selas Corp. of America in 1958 after three years at Minneapolis-Honeywell's Brown Instrument Research Div., Philadelphia, where, as senior research engineer, he made several inventions (with patents applied for) including an analog-to-digital pneumatic converter and a continuous hydrostatic transmission. Earlier he was a project engineer at ITE Circuit Breaker Co. and a consulting engineer with A. C. Caldwell. A native of China, he came to the United States in 1945 to the U.S. War Dept. as an interpreter in a program for training Chinese pilots at Army Air Force flight schools here. He received his M.S. degree in me-

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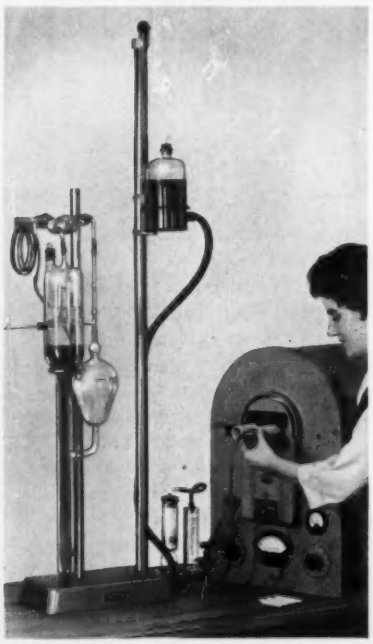

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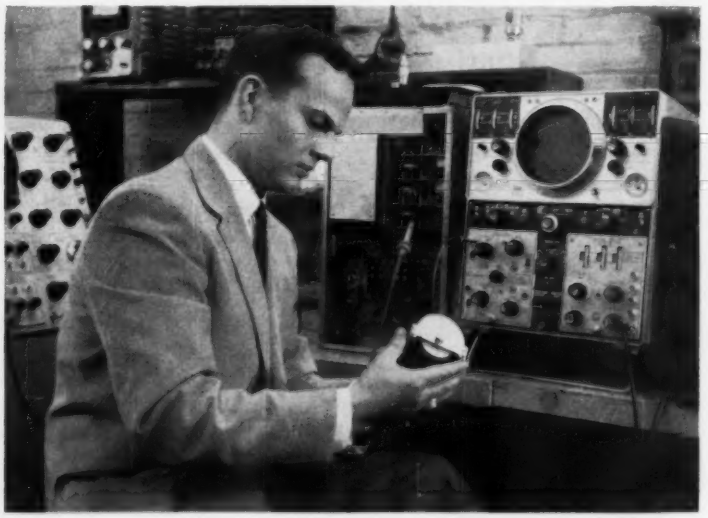
C. L. Feng Directed Development of Selas' "Thermoloy", an Analog Simulator

chanical engineering from the University of Pennsylvania's Towne School in 1954, an M.S. in mathematics from Temple University in 1957 and is now well along the way toward his doctorate in physics.

Although his time is well filled with his technical work and continuing studies, he has managed to develop a wide range of hobbies — including private flying, fencing (he was a member of Penn's Junior Varsity Fencing Team), ballet dancing, photography and sign language.

The fourth in our series on Nondestructive Testing for Management considers factors in selecting ultrasonic testing equipment and is written by **R. A. Seidel** of Westinghouse who, since joining the company in 1957, has been responsible for the development of new nondestructive testing techniques and instrumentation design.

R. A. Seidel Studies an Ultrasonic Search Unit for Quality Testing Large-Generator Rotor Forgings



A graduate electrical engineer of the University of Pittsburgh, he was a microwave field engineer with the American Telephone & Telegraph Co. for over eight years. He has designed several features of ultrasonic test instrumentation which have been adopted by various manufacturers and is presently vice-chairman of the Pittsburgh S.N.T. chapter. Other interests, shared by his wife, Virginia, include golf, gardening, and sports car mechanics – and their two children Robert Jr. (3) and Susan (3 months).

H. N. Hill, author of "Residual Welding Stresses in Aluminum Alloys", has been on the staff of the Alcoa Research Laboratories since 1927. After receiving his B.S. degree from the University of Pittsburgh in that year, he joined the company as research engineer; he was named chief of the engineering design division in 1955 and last year appointed scientific advisor. He went on to graduate work at Carnegie Institute of Technology and received his M.S. degree in 1938.

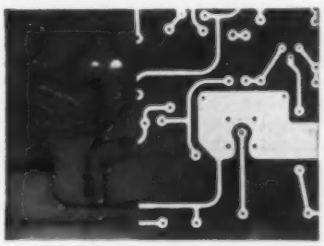
He lists his hobby as "rural living." He lives on a 100-acre farm with his family–he and his wife have a young son and four grown daughters – where he does his own building, as evidenced by the photo above.

A metallographic technique developed at Universal-Cyclops Steel Corp. for electrolytic polishing of refractory metals is reported by **F. R. Cortes** in his article on p. 97. Metallurgist in the Refractomet Div. of Universal-Cyclops, he came to the company in 1958 as research assistant on refractory and reactive metals. After graduating from Carnegie Institute of Technology in 1955 with a B.S. in metallurgical engineering, he worked at Bethlehem Steel Co. on quality control problems, then in 1956 joined Crucible Steel Co. as a research assistant in their project engineering department.

Straits Tin Report

Chemical tinning enhances the solderability of the conductive paths of printed circuits. Pure tin is deposited only on metal surfaces, including exposed edges; dielectric properties are unchanged.

The new process, using "CUPOSIT LT-26," made by Shipley Co., Inc., Wellesley, Mass., is not a substitute for electrodeposited tin, but it affords protection to the printed circuit board, thereby increasing storage life. "CUPOSIT LT-26" operates at temperatures lower than hot tin dipping, requires no electricity, contains no cyanide.



Bright side of printed circuit shows results of immersion in new chemical tinning process.

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• *High-temperature brazing filler* metal alloys of tin, nickel, chromium, silicon keep joints strong after long exposure at high temperatures.

• *Low-melting quaternary* alloys of tin, indium, lead, silver are used for cryogenic circuits.

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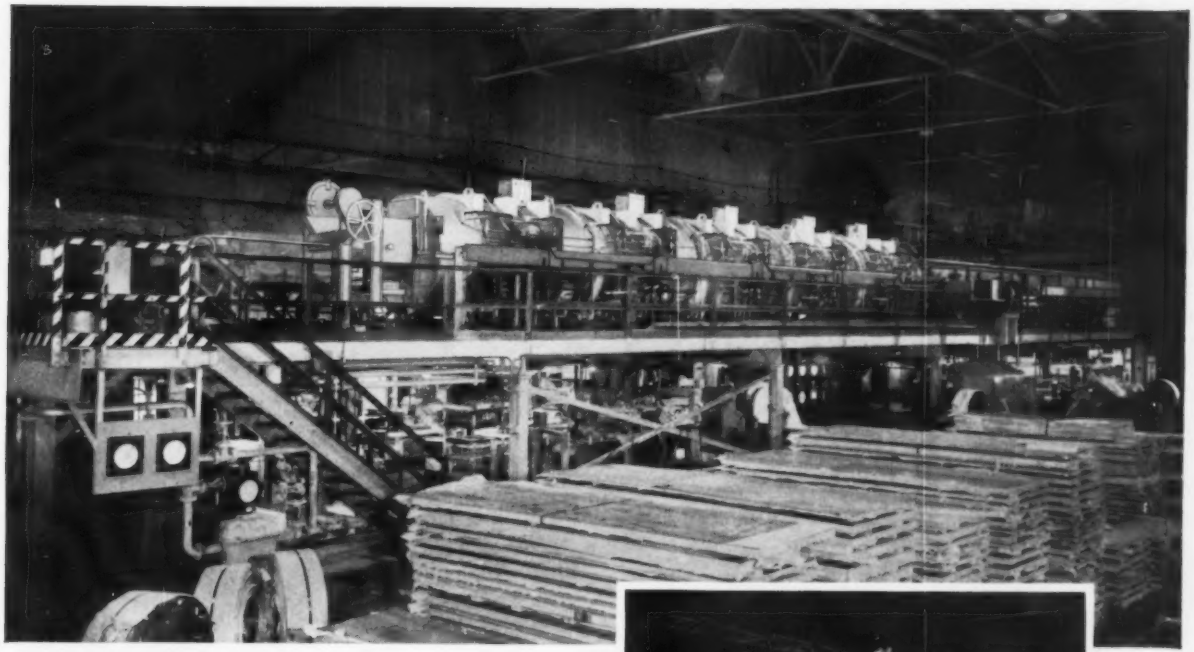

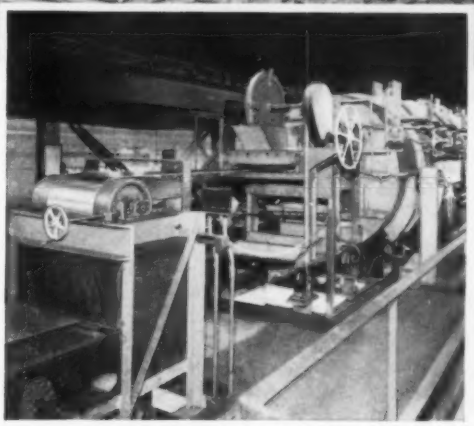

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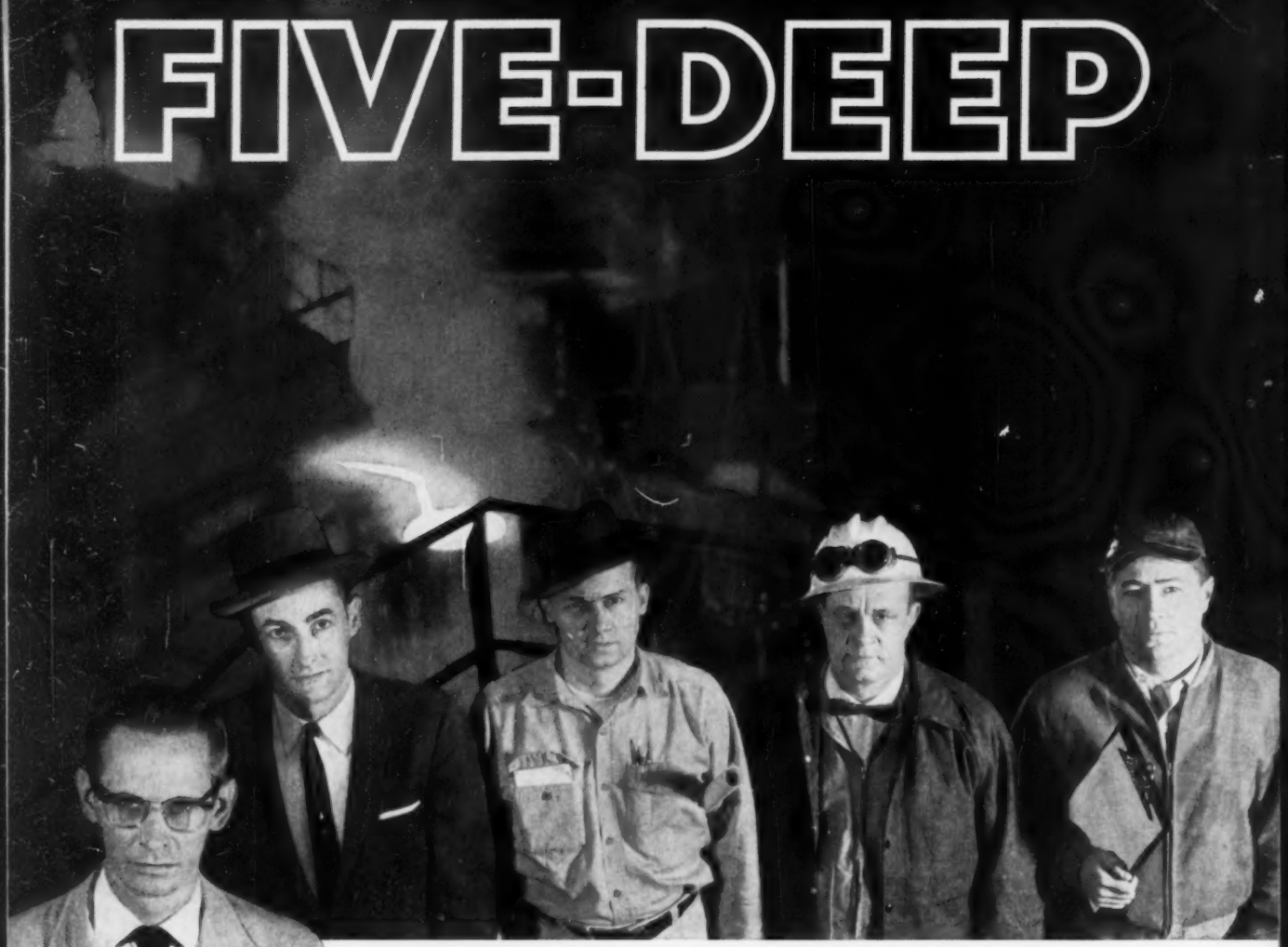

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